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CHEMICAL SECTION.

Stated Meeting of March 19, 1895.

DR. W. C. DAY, President, in the Chair.

[The President announced the paper for the evening, and introduced the speaker.]

COMPOSITION OF THE AMERICAN SULPHUR PETROLEUMS.

BY CHARLES F. MABERY,
Professor of Chemistry, Case School of Applied Science.

[*Concluded from vol. cxxxix, p. 424.*]

OHIO PETROLEUM.

Aside from our own publications on the sulphur compounds in Ohio oil (*Proc. Amer. Acad*, **25**, 218; *Amer. Chem. Journn.* **16**, 83), and those of Orton (Ohio State Geological Reports for 1886, 1888, 1890; and United States Geological Report, 1886–87), I have seen no published statements concerning the composition of the Ohio sulphur petroleum. The crude oil, that has formed the basis of this work, was received from the Peerless Refining Company, Findlay, O.,

which controls a large section of oil territory. This oil was somewhat thicker in consistency than Pennsylvania oil, with a slight odor of hydric sulphide, and it contained a small quantity of water which was slowly removed by fused calcic chloride. Its specific gravity at 20° was found to be 0·838.

A determination of sulphur gave 0·72 per cent., a value somewhat higher than we have hitherto obtained, 0·55 per cent. Markownikoff and Ogloblin obtained in Apsheron petroleum 0·064 per cent. and in the Transcaspian oil 0·16 per cent.

A combustion in oxygen with a layer of plumbic peroxide in front to retain the sulphur (Warren, *Proc. Amer. Acad.*, **6**, 472) gave the following percentages of carbon and hydrogen: Carbon, 84·57; Hydrogen, 13·62.

Bromine absorption in the crude oil and in some of the fractions was determined by the method given in Allen's *Commercial Organic Analysis*, Vol. II, page 388, with the following results:

Fraction.	*Percentage of Bromine Absorbed.*
110°–150°	0·73
150°–220°	1·74
220°–257°	4·84
257°–300°	5·04
300°–330°	12·1
Residue	19·5

A determination of the bromine absorption in the crude oil gave 6·1 per cent.

The distinctive qualities of Ohio oil appear also in the proportions which distill at different temperatures; 800 grams of the crude oil distilled in the following proportions, beginning at 110°:

	110°–150°	150°–220°	220°–257°	257°–300°	300°–350°	Residue
Grams . . .	76	133	86	76	69	348
Per cent. .	9·75	16·63	10·75	9·75	8·63	43·5
Sp. Gr. at 20°	0·7282	0·7669	0·7940	0·8138	0·8242	0·8976
Per cent. sulphur	0 10	0·38	0·41	0·37	0·37	0·54

The distillates below 225° were not appreciably decomposed, since they were free from color and odors resulting from decomposition. At somewhat higher temperatures

the distillates were colored, with characteristic penetrating odors. It was, therefore, evident that in the refinery distillation of Ohio oils cracking begins in the vicinity of 250°. There is evidence that certain extremely unstable constituents of the crude oils, when separated, decompose on standing, and no doubt similar decompositions take place, perhaps more slowly, when they are dissolved in other portions of the oils. At the beginning of the distillation, hydric sulphide appears to some extent, but the higher fractions are nearly free from it. Considerable sulphur is lost during distillation, as shown by analyses of the crude oil and of products obtained from it. In determining experimentally what became of the sulphur evolved, it appeared to escape mainly as hydric sulphide, with the separation in small quantity of free sulphur and perhaps in still smaller quantities as volatile sulphur compounds.

The ash obtained by igniting the residue from the distillation of the volatile portions of petroleum, has frequently been examined. Traces of metals, gold, silver and copper have been found, as well as the oxides of calcium, iron and aluminum. In the ash of Caucasus petroleum Markownikoff and Ogloblin found substantially the same composition, and the quantity of ash calculated for the original quantity of crude oil amounted to 0·09 per cent. In the coke from Ohio petroleum, we have found 95·06 per cent. of carbon, 4·85 per cent. of hydrogen, and 0·11 per cent. of ash.

It has already been mentioned that all petroleums are regarded by some chemists as having a similar composition, the difference in properties depending upon a variation in the proportions of the constituents. The Caucasus petroleum contains but a small proportion of the series C_nH_{2n+2}, and the Pennsylvania oil, so far as it has been examined, contains the series C_nH_{2n} in much smaller proportions than the Russian oil. Referring the sulphur in Ohio petroleum to the average composition of the compounds containing it, the sulphur derivatives should amount to at least five per cent. of the crude oil. Such a proportion of sulphur compounds must necessarily exert an important influence on the properties of the crude oil as well as of the products ob-

tained from it. To ascertain, therefore, the relation in which the Ohio sulphur oil stands to the other two petroleums in question, it seemed necessary to submit the Ohio product to an examination for all constituents. We have undertaken to determine first the presence of the hydrocarbons C_nH_{2n+2}, with the approximate quantity of each member of this series, except those with low boiling points.

HYDROCARBONS C_nH_{2n+2}.

For the separation of the members of this series, we procured twenty-five liters of the most volatile refinery distillates collected from a 300-barrel still. This product was subjected to distillation in quantities of eight liters each, with the aid of a Warren condenser filled with a mixture of salt and ice, ice alone or water dependent upon the boiling point of the distillate collected, placing in front of the condenser another containing the freezing mixture. To collect any gas that might escape during the distillation, a delivery tube dipping beneath an inverted receiver filled with water was connected to the bottle receiving the distillate. At first, a very small quantity of gas collected, which burned with a smoky flame, but none afterward. In refinery distillation of the Ohio oil, gases escape in considerable quantities before distillates condense, but we have not yet examined them. With the exception of hydric sulphide, probably these gases do not differ essentially from those which are evolved at the beginning of the distillation of Pennsylvania oil. I am not aware that the composition of the gas from Ohio oil wells has been determined, but it is probably not very different from that of the gas issuing from the Pennsylvania wells which Sadtler (*Amer. Chem.*, **7**, 97) found to consist principally of methane, with smaller quantities of ethane, hydrogen, carbon dioxide and nitrogen. In the gas from the Canadian wells at Enniskillen, Fouqué (*Compt. Rend.* **67**, 1045) found marsh gas, ethane, and small quantities of carbonic dioxide.

The first distillates were subjected to further distillation until a considerable quantity collected that distilled tolerably constant within narrow limits of temperature, corre-

sponding to the boiling points of the hydrocarbons. Between 0° and 1°, 35 grams collected, which distilled for the most part at 0°, barometer 741 mm., corresponding to the boiling point of butane. At 7°-9°, 20 grams of a distillate collected, corresponding to the hydrocarbon which was separated by Warren from Pennsylvania petroleum, and which he regarded as one of the butanes. Of the two possible butanes there can be no doubt that one boils at 0°, and Butlerow (*Ann. Chem. Pharm.* **144**, 10) obtained from isobutyl alcohol a butane to which he assigned as the boiling point —17°·5. Since, therefore, there seems to be some question concerning the product which he collected at 8°, more of this distillate will be procured for the study of its chemical behavior to ascertain whether it be a definite compound.

Between 29° and 30°, barometer 747 mm., the distillate amounted to 75 grams, and a vapor density determination gave the value required for isopentane; found 2·52, required for pentane, 2·49. At 37°-38°, 75 grams distilled, and this product gave as its vapor density, 2·49; required for normal pentane, 2·49. At 60°-61°, 50 grams collected, which gave a vapor density required for isohexane; found, 2·94; required, 2·98. The quantity of product collected at 67°-68° gave as its vapor density, 3·00; required for normal hexane, 2·98. On account of the manner in which these distillates were collected, the weights afford no information concerning the proportions in which they are contained in the crude oil, although they are evidently present in much smaller quantities than in Pennsylvania oil.

For the separation of the hydrocarbons with higher boiling points, the fraction —150° from the crude oil distilled *in vacuo*, was submitted to further distillation under atmospheric pressure. 41·5 kilos of crude Findlay oil was distilled under a tension of 50 mm., and products separated within the limits —100°, 100°-150°, 150°-200°, 200°-250°, 250°-350°, and the residue above 350°, which was preserved. These products collected with but slight decomposition and without the disagreeable odors characteristic of refinery distillates. On account of the reduced pressure, doubtless some of the more volatile constituents were lost, and in

subsequent operations scarcely any distillate collected below 30°. Within these limits the distillate collected in the following proportions:

	−100°	100°–150°	150°–200°	200°–250°	250°–350°	Residue.
Grams	8000	8520	6480	7700	2670	9000
Per cent. . .	18·6	19·8	15·1	18·	6·2	20·9

The following results were obtained in determining the specific gravity of the distillates:

−100°	100°–150°	150°–200°	200°–250°	250°–350°	Residue.
0·7445	0·7941	0·8245	0·8455	0·907	0·9139

No hydric sulphide was detected in the fraction —100°, but it was present in small quantities in the higher fractions. The percentages of sulphur were determined by combustion in air,

	−100°	100°–150°	150°–200°	200°–315°	Residue.
Percentage of sulphur	0·054	0·25	0·42	0·61	0·67

A comparison of these results with the percentages of sulphur in the distillates collected under atmospheric pressure (see p. 2) shows the influence of distillation *in vacuo*, diminishing the quantity of sulphur in the lower products. This is one of the desirable features of vacuum distillation for the sulphur petroleums.

The portion collected below 150° in the first distillation was submitted to a series of separations under atmospheric pressure with the aid of Hempel and Warren condensers. In successive distillations collecting within 5°, within 2°, and finally within 1°, the distillates collected rapidly within limits of temperature corresponding to the boiling points of the well-known hydrocarbons C_nH_{2n+2}, and at certain other points where an equilibrium in boiling points seemed to be established by mixtures of lower and higher products. To separate the constituents of such mixtures required long-continued distillations, but for the most part it was evident that they corresponded to no individual hydrocarbons. In purifying the distillates containing the hydrocarbons for determination of vapor density, they were first shaken with alcoholic mercuric chloride to remove the sulphur compounds. The sulphur remaining in solution after this treat-

ment was usually less than 0·03 per cent., provided the compound, R_2SHgCl_2, was crystalline, as was observed in most of the fractions below 150°. In fractions with higher boiling points the mercury is held in solution, either as the molecular compound of the sulphide or in some other combination, with such persistence that it can be removed only by the prolonged action of hydric sulphide on the hot distillate. In some of the sulphur oils hydric sulphide in the cold will not precipitate the mercury. This solvent action of the sulphur oils on metals, metallic oxides and certain other compounds seems to be a characteristic property which has also been observed in other petroleums. Macadam (*Journ. Chem. Soc.*, **34**, 355) ascertained that certain metals, such as lead, solder and zinc, are quite readily acted upon, and that some oils exert a greater solvent action than others. This solvent action was attributed by Macadam to the hydrocarbons, but Engler (*Ber. der deutsch. Gesellsch.*, **12**, 2186) repeated the experiments of Macadam and ascertained that metals are not affected when air is excluded. Engler, therefore, concluded that acid compounds are formed in the oil by exposure to air which dissolves metallic oxides. Without doubt the purification of refined distillates from the sulphur petroleum by agitation with an alkaline solution of plumbic oxide depends, in part, at least, upon the solvent action of certain constituents of the oil. It may be that the solvent action is due to the combined effect of the oxygen and the sulphur compounds, assuming, of course, that oxygen compounds are contained in the sulphur petroleums which, from the analogy of other oils, may, at least, be regarded as probable. This subject will receive further attention when we reach the higher distillates.

For further purification each fraction was agitated, first with concentrated nitric, then with concentrated sulphuric acid, and finally heated for some time under a vertical condenser with metallic sodium. The fractions in the vicinity of 80° will be considered with the aromatic series. The distillate collected at 89°–90°, barometer 754 mm., gave a vapor density 3·43, corresponding to that of isoheptane, 3·46. At 96°–97°, 50 grams distilled constant, barometer 744 mm.,

and the vapor density of this product was found to be 3·42; required for heptane, 3·6. No other oils were collected in any considerable quantity below 109°, the point where toluol began to appear. Fifty grams distilled constant at 119°–120°, barometer 749 mm., and gave as its vapor density 3·89; the vapor density required for octane is 3·94. Since there seems to be some doubt concerning the existence of an octane at this point, this fraction was carefully purified in the manner described above, followed by prolonged boiling with sodium. Determinations of carbon and hydrogen, and of vapor density gave results agreeing closely for values required for octane. As further proof of the existence of a hydrocarbon with this boiling point, a considerable quantity has been prepared for the purpose of trying the action of a chlorine and the formation of other derivatives.

Warren (*Mem. Amer. Acad.* (N. S.), **9,** 156) separated a constituent of Pennsylvania petroleum which distilled constant at 119°·5, with a vapor density corresponding to that of octane. From the particular care with which the determinations of Warren were made, there can be no doubt concerning the existence of a hydrocarbon in Pennsylvania petroleum with this boiling point. Although Beilstein and Kurbatoff recognized hexahydroisoxylol in a distillate of Pennsylvania petroleum collected at 119°·5, it is probably not the principal constituent with this boiling point; it certainly does not constitute the main portion of this fraction in Ohio petroleum. In a distillate from coal Schorlemmer (*Journ. Chem. Soc.*, **15,** 419) separated an octane boiling at 119°–120°, and subsequently (*Ann. Chem. Pharm.*, **127,** 311) he identified the same body boiling at 119° in petroleum. But in the treatise on Chemistry, by Roscoe and Schorlemmer, New York, 1886, it is stated that the three octanes known are: normal octane, boiling point 125°·46, found in petroleum; tetramethylbutane, boiling point 108°·5; and hexamethylethane, melting at 96°–98° and boiling at 105°–106°.

Above 120°, after the eleventh distillation, the distillates collected in considerable quantities within the limits of 1°:

	120°–121°	121°–122°	122°–123°	123°–124°	124°–125°	125°–126°	126°–127°	127°–128°
grams	35	40	80	70	75	75	60	40

After prolonged distillation considerable quantities still collected at 122°–125°, and they contained a small quantity of aromatic hydrocarbons. We are collecting larger quantities of these oils for study of their behavior towards chemical reagents. The greater portion of the fractions 125°–130° were lost in an accident after the eleventh distillation; but sufficient was preserved, distilling at 127°–128°, for a vapor density determination which gave 3·85; required for C_8H_{18}, 3·94. The liquid collected between 127°–128°, by Warren at this point, was found to have the boiling point 127°·6; the vapor density found by Warren was 3·99.

All the distillates between 115° and 130° evidently need to be carefully examined with larger quantities of oil. The portion collected at 130°–145° will be considered in connection with the aromatic compounds.

The fractions collected between 144°–148° were small in quantity after long-continued distillation. Eighty-five grams were collected at 149°–151°, of which forty grams distilled constant at 149°–150°, barometer 756 mm., and a vapor density determination gave 4·63, required for C_9H_{20}, 4·43; boiling point of nonane 150°·8 (Warren). Below this point, Ohio sulphur petroleum seems to contain members of the series C_nH_{2n+2}, corresponding to those which have been recognized in Pennsylvania oil, but in smaller quantities. They form one-fifth of the crude Pennsylvania oil and but one-tenth of the Ohio oil. It has not seemed necessary to obtain further evidence than is necessary to show the similarity of the Ohio products with those which have been found in the Pennsylvania oil. This portion of our work may seem to possess less interest than the study of the higher boiling fractions, yet it has appeared of sufficient importance to justify the necessary expenditure of time and effort. The higher fractions have been quite thoroughly distilled, and these products, with the residue above 350° of the first vacuum distillation, are reserved for future study.

AROMATIC HYDROCARBONS.

Series C_nH_{2n-6}.

Benzol.—After the sixth distillation, 25 grams collected at 77°–79°, 35 grams at 79°–81°, and 20 grams at 81°–83°. Ben-

zol was determined in these fractions by treating a weighed quantity with a mixture of nitric and sulphuric acids, distilling off the hydrocarbons not affected and weighing them and the residual nitrobenzol. The fraction 77°–79° gave 3 per cent. of benzol; the fraction 79°–81°, 15 per cent.; and the fraction 81°–83°, 5·8 per cent. The fractions 75°–76° and 85°–86°, when treated in the same manner, left scarcely any residual nitro-product after distillation, and the slight residue gave no reaction for aniline with furfurol after reduction with tin and hydrochloric acid and distillation. This quantity of benzol, calculated for the 41·5 kilos of crude oil taken, amounts to 7·16 grams, or 0·017 per cent., which represents approximately the quantity of benzol in the crude oil.

Toluol.—In examining the fraction 107°–113° after the sixth distillation for toluol, a weighed quantity of the oil was treated with nitrosulphuric acid, keeping the solution cold. On standing, crystals of dinitrotoluol separated, which were identified by their melting-point, 71°. The portion of the oil not affected by the acid was removed by distillation, and the quantity of toluol corresponding to the residual hydrocarbon was 1·14 per cent. of the total distillate in the fraction 107°–109°, to 13·07 per cent. in the fraction 109°–111°, and 2·8 per cent. in the fraction 111°–113°; the total weight of the first fraction was 50, of the second 80, and of the third 65 grams. The total weight of toluol was, therefore, 12·84 grams, corresponding to 0·03 per cent. in the 41·45 kilos of crude oil, which may be accepted as the approximate quantity of toluol in Ohio petroleum. The fraction 114°–115°, when treated in a similar manner, gave a nitro-product which was apparently unchanged by reduction, since it would not dissolve in acids; it must, therefore, be derived from another series, perhaps from an unsaturated hydrocarbon, C_nH_{2n}.

Xylols.—Metaxylol has been identified in various petroleums, having been found first together with other homologues of benzol by De la Rue and Müller (*Proc. Roy. Soc.*, 1856, 221) in the Rangoon petroleum. Of the other isomeric xylols only the para-compound has been recognized, and that by Pawlewski in Galician petroleum.

Our products were collected, after twenty distillations, at intervals of 1° between 136° and 142°, the greater portion distilling at 137°–138°, 139°–140° and 141°–143°. These fractions were readily acted upon by nitric acid, forming nitro-compounds or oxidation products according to the form of the reaction. In testing for the presence of para-xylol in fraction 137°–138°, a portion was treated with a mixture of nitric and sulphuric acids, at first in the cold, then with the aid of a gentle heat. After distillation of the portion not affected, a brown oil remained, which deposited a crystalline solid on standing, and, after crystallization from alcohol, a substance formed in glistening white needles melting at 139°–140°. It was, therefore, trinitro-p-xylol, melting-point 139°–140° (Nölting and Geissmann, *Ber. der deutsch. chem. Gesellsch.*, **19**, 144). Another portion of the same fraction with fuming nitric acid in the cold gave long, yellow needles, sparingly soluble in alcohol, melting at 145°; therefore, dinitro-p-xylol, melting-point 147°–148° (Lellman, *Ann. Chem. u. Pharm.*, **228**, 250). For further confirmation, more of the same oil was boiled for some time with chromic acid, and the solution extracted with a considerable quantity of ether. The solid remaining after evaporation of the ether appeared in the form of minute prisms which were insoluble in water, but dissolved readily in sodic hydrate, and sublimed without melting. The properties of this substance, therefore, corresponded to those of terephthalic acid. Another portion of the same oil when heated thirty hours, after distillation of the hydrocarbon not affected, left only an oily product. Upon heating a much longer time the oily residue was neutralized with sodic hydrate evaporated to dryness, the salt decomposed with hydrochloric acid, and the solution extracted with ether; the crystalline solid left by evaporation of the ether was probably p-toluic acid, but it was not obtained in quantity sufficient for identification.

Metaxylol.—After heating a portion of the fraction 139°–140° with a mixture of nitric and sulphuric acids during forty-eight hours, and distilling the oil not affected by the acids, the solid which remained, together with the crystals

collected on cooling the acid mixture, was purified by crystallization from hot alcohol; the long, slender, colorless needles thus obtained melted at 175°–176°, showing its identity as trinitro-m-xylol, melting point 176°.

In the fraction 141°–143° several attempts were made to ascertain the presence or absence of orthoxylol, but the nitro-products and the acids resulting from oxidation were not obtained in sufficient quantities to distinguish them from the corresponding derivatives of metaxylol.

Approximate quantitative determinations of the xylols showed that they were present in the crude oil in very small proportions. In the fraction 137°–138°, the quantity of paraxylol corresponded to 0·021 per cent. in fraction 139°–140°, the quantity of metaxylol to 0·016 per cent. The quantity of xylol found in the distillates 142°–143° corresponded to 0·021 per cent. of the crude oil; and, since the presence of orthoxylol is doubtful, the xylol in these fractions was probably the meta-compound. Although the distillation of these portions was long-continued, the xylols were evidently not all collected in their respective fractions. At least one-third should be added to the percentages given above from outside sources.

There were indications in the distillates 130°–140° of other constituents capable of forming nitro-products, perhaps ethylbenzol and hexahydromesitylene. Attempts were made to identify these bodies, but the quantities of the distillates were insufficient. Further examination for these bodies will be made with larger quantities.

SERIES C_nH_{2n}.

Hexahydro compounds (Beilstein and Kurbatoff); naphtenes (Markownikoff and Ogloblin).

This series of hydrocarbons, so far as they have been investigated, include the following members:

	Boiling Point.
Hexahydrobenzol (C_6H_{12})	69°
Hexahydrotoluol (C_7H_{14})	96°
Hexahydroisoxylol (C_8H_{16})	118°
Hexahydromesitylene (C_9H_{18})	135°–138°
Hexahydrocumol (C_9H_{18})	147°–150°
Hexahydrocymol ($C_{10}H_{20}$)	171°–173°

In examining the distillates from Ohio petroleum for the hydrocarbons of this series, beginning with hexahydrobenzol, the fraction 69°–70°, after the fourteenth distillation, was shaken with concentrated nitric acid, with concentrated sulphuric acid, and then heated to boiling with metallic sodium. Determinations of carbon and hydrogen in the oil thus purified gave results corresponding to the composition of hexane:

I. 0·1618 gram of the oil gave 0·4934 gram CO_2 and 0·2299 gram H_2O.

II. 0·1891 gram of the oil gave 0·5790 gram CO_2 and 0·2663 gram H_2O.

	Required for		Found.	
	C_6H_{14}	C_6H_{12}	*I.*	*II.*
C	83·72	85 71	83·18	83·51
H	16·28	14·28	15·79	15·65

Hexahydrobenzol is therefore not present in Ohio oil.

The fraction 96°–97°, barometer 750 millimeters, after the fourteenth distillation, was purified as before, and its composition determined by analysis:

0·2083 gram of the substance gave 0·6423 gram CO_2, and 0·2849 gram H_2O.

0·2010 gram of the substance gave 0·6200 gram CO_2, and 0·2744 gram H_2O.

	Required for.		Found.	
	C_7H_{16}	C_7H_{14}	*I.*	*II.*
C	84·00	85·71	84·09	84·72
H	16·00	14·28	15·27	15·17

This oil was evidently heptane, C_7H_{16}, the low percentage of hydrogen indicating perhaps a trace of hexahydrotoluol. Another portion of the fraction was then boiled for some time with a mixture of nitric and sulphuric acids, distilled over sodium and analyzed. The percentage of carbon and hydrogen corresponded to the composition of heptane: Carbon, 83·75; hydrogen, 16·28.

In a distillate 95°–100° from American ligroine, Beilstein and Kurbatoff found 84·3 per cent. of carbon and 15·4 per cent. of hydrogen. After prolonged heating with dilute nitric acid, the oil distilled at 98°·5–99°·5, and gave, on analysis, 84·2 per cent. of carbon and 15·9 per cent. of

hydrogen, from which it was inferred that hydrocarbons poorer in hydrogen, were contained in the crude ligroine.

Hexahydroisoxylol (Octonaphtene, Markownikoff).—Hexahydroisoxylol was found by Beilstein and Kurbatoff in Caucasus petroleum (*Ber. der deutsch. chem. Gesellsch.*, **13**, 1818), and in American ligroine (*ibid*, **13**, 2028); since the American source was not mentioned, it is to be inferred that the ligroine was prepared from Pennsylvania oil. In testing the fraction 118°–119°, fourteenth distillation, for hexahydroisoxylol, a portion of the oil was heated forty hours with a mixture of nitric and sulphuric acids. On cooling, long, flat plates separated from the oil, nearly insoluble in cold, more readily in hot alcohol. After crystallization from alcohol, this substance melted at 178°, and was, therefore, trinitroisoxylol. A similar nitro-product, with the same melting point, was obtained from the fraction 123°–124°. There can be no doubt that the trinitroxylol obtained from fraction 118°-119° indicated the presence of hexahydroisoxylol since the prolonged distillation precluded the possibility that this fraction contained metaxylol. As it appeared in the study of this fraction, hexahydroisoxylol was present only in very small quantity.

After agitating thoroughly a portion of the same distillate with a mixture of nitric and sulphuric acids, and distilling over sodium, analysis gave percentages of carbon and hydrogen required for octane:

	REQUIRED FOR		FOUND.	
	C_8H_{18}	C_8H_{16}	I.	II.
C	84·20	85·71	84·42	84·28
H	15·79	14·28	15·19	15·08

Since the percentage of hydrogen is somewhat too low, it is possible that the hexahydro-compound was not entirely removed by the treatment with acids, especially as we have found that prolonged heating with the acid mixture is necessary even to form a crystalline nitro-product.

In describing the properties of hexahydroisoxylol, Wreden found that it was readily converted by a mixture of nitric and sulphuric acids into trinitro-meta-xylol, and Baeyer made a similar observation concerning hexahydrome-

sitylene. On account of the slow formation of the nitro-derivative in the oil separated from petroleum, Markownikoff doubted the identity of octonaphtene and hexahydroisoxylol. There seems to be no difficulty in forming the nitro-compound, at least in the oils we have in hand, although considerable time is required for its formation, possibly due to the dilution by other constituents.

After long-continued boiling of this distillate with the acid mixture, followed by successive treatment with sodium until distillation left no residue, analysis gave results required for octane:

Carbon, 84·20; hydrogen, 16·10.

CANADIAN PETROLEUM.

Under the general title of American petroleum, with occasional reference to Pennsylvania and to Canada as the particular sources, several partial examinations were early made of crude Canadian oil by French and English chemists. Pelouze and Cahours were the first to establish the presence of the series C_nH_{2n+2}, and Schorlemmer recognized the presence of benzol, toluol and cumol in "real Canadian rock oil, a thick black liquid of a very unpleasant odor."

My first acquaintance with Canadian petroleum was in 1890, when I procured some of the crude oil and also a quantity of the "sludge" from the refining of burning oil for the purpose of examining the sulphur compounds. The peculiar features of the distillates in a preliminary examination (*Am. Chem. Journ.*, **16**, 89) seemed especially inviting, and I decided to undertake, with the aid of the refiners, as complete an examination for the principal constituents as was possible with the appliances at my command.

The products which I obtained from the refinery of Messrs. Samuel Baker & Co., at Petrolia, for the study of Canadian petroleum, included a barrel of crude oil, considerable quantities of the first distillate, naphtha distillate, and burning oil distillate, none of which had been further refined, besides 200 litres of thoroughly washed oil from "sludge acid." The crude oil was thick and nearly black in color, with the peculiar penetrating odor characteristic of the

sulphur oils. It contained hydric sulphide in small quantity and some water, which was removed after long standing with fused calcic chloride. A determination of the specific gravity of the crude oil at 20° gave 0·8821. A former determination in another sample of crude oil gave 0·8600 (Mabery, *Am. Chem. Jour.*, **16**, 90). These results differ widely from certain others hitherto reported. H. P. Brummel (*Can. Geol. Rep.*, 1888, 89) gave, as the specific gravity of Canadian oil, 0·804 and 0·808. Markownikoff and Ogloblin (*Ann. Chim. Phys.*, VI, **2**, 372) referred to results by Deville which gave 0·844 as the specific gravity of Canadian oil, and 0.887 as the specific gravity of Ohio oil. The specific gravity of the oils at Petrolia was given by Redwood (*Journ. Soc. Chem. Ind.*, 1887, 405) as 0·859–0·877, and of those at Oil Springs somewhat lower, 0·844–0·854. We found the specific gravity of the latter oil to be essentially the same—0·8442. Probably, as Engler observed in the Elsass oils, the specific gravity diminishes with the depth of the well.

Determinations of sulphur in the crude oil gave the following results:

	I.	II.	III.
Per cent. Sulphur,	0·98	0·99	1·06
	(By Carius.)	(By combustion in air.)	

The Canadian petroleum contains somewhat less carbon and hydrogen than Ohio sulphur oil:

	Canadian.	*Ohio.*	*Pennsylvania.*	*Russian.*
C . .	83·94	84·57	84·19	86·89
H .	13·37	13·62	13·70	13·18

In the Canadian Geological Report, 1888–1889, Brummel gave eighty-five per cent. for carbon and fifteen per cent. for hydrogen, but these results are evidently only approximately correct. The percentages of carbon, hydrogen and oxygen in Canadian oil, as found by Pelouze and Cahours, are as follows:

	C.	H.	O.
I	84·2	13·4	2·3
II	84·3	13·5	2·0

In a distillation of the Canadian oil under atmospheric pressure, the following weights were obtained from 800 grams, the distillation beginning at 115°:

	115°–150°	150°–200°	200°–250°	250°–300°	300°–350°	Residue.	Loss.
Weights . .	22	62·5	72	43	27	561	12
Per cent. .	2·75	7·8	9·5	5·1	3·1	70·1	1·75
Specific Gravity,	0·767	0·8026	0·8228	0·8345	0·9037		

A comparison of the distillates at different temperatures of oils from other localities has been included in considering the properties of the Ohio oil. A clearer idea may be gained of the peculiar character of the Canadian oil by comparing the distillates from it with those from other fields:

	Apsheron.		Pennsylvania.	
	Per Cent.	*Specific Gravity.*	*Per Cent.*	*Specific Gravity.*
120°–150° . .	0·5		19·75	
150°–200° . .	10·9	0·786	8·75	0·757
200°–250° . .	12·8	0·824	15·23	0·788
250°–320° . .	24·7	0·861	20·7	0·809
	47·9		64·43	
Residue . .	52·1		35·57	

Canada.			Ohio.		
	Per Cent.	*Specific Gr.*		*Per Cent.*	*Specific Gr.*
115°–150°	2·75	0·767	110°–150°	9·75	0·7282
150°–200°	7·8	0·8026	150°–220°	16·63	0·7669
200°–250°	9·5	0·8228	220°–257°	10·75	0·7940
250°–300°	5·1	0·8345	257°–300°	9·75	0·8138
300°–350°	3·1	0·9037	300°–350°	8·63	0·8242
	28·25			55·51	
Residue . .	70·10			43·00	

In the percentages of the lower fractions it will be seen that the Canadian oil resembles more nearly the Russian oil, but the residue above 350° is somewhat larger than in the oils from other localities. As will appear later, this difference is much less in distillations conducted *in vacuo.*

The percentage of sulphur was determined in each distillate by combustion in air:

	115°–150°	150°–200°	200°–250°	250°–300°	300°–350	Residue.
Per cent. of sulphur,	0·28	0·42	0·50	0·51	0·86	0·70

Determinations of the quantity of bromine absorbed indicated slight differences in the capacity for absorption between the higher fractions and those from Ohio oil:

Canada. Fraction.	Canada. Per Cent. of Br. Abs.	Ohio. Fraction.	Ohio. Per Cent. of Br. Abs.
115°–150°	0·67	110°–150°	0·73
150°–200°	1·12	150°–220°	1·74
200°–250°	3·49	220°–257°	4·84
250°–300°	8·39	257°–300°	5·04
300°–350°	14·4	300° 330°	12·1
+350°	17·8	+330°	19·5

The percentage of bromine absorbed by the crude oils was nearly the same.

Canada.	Ohio.
15·11	10·19

Below 200° the decomposition was slight, the distillates were colorless and hydric sulphide escaped only in small quantities. Above this point the distillates began to appear yellow with the disagreeable odor of decomposition. It is probable that cracking begins near this temperature affecting the unsaturated hydrocarbons, if they are present, and perhaps other series as well as the sulphur compounds. Certain constituents of the Canadian oil seem to be more unstable than those of Ohio petroleum. The tendency towards polymerization of unsaturated hydrocarbons, separated from distillates corresponding to burning oil, was observed by me (*Amer. Chem. Jour.*, **16**, 92) in an oil that had stood two years after prolonged distillation. When again heated, it suddenly polymerized into a higher product that could not be distilled without decomposition. The conversion of Canadian petroleum into pitch, upon long standing exposed to the weather, may be observed at Oil Springs. It is probably caused by evaporation or absorption of the more volatile portions of the crude oil and polymerization of unstable constituents.

Determinations of carbon and hydrogen were made in a specimen of coke from Petrolia oil with the following results:

	Coke from Petrolia Oil. I.	Coke from Petrolia Oil. II.	Oil Springs Pitch.
C	94·04	94·34	64 86
H	4·19	4·34	8·13
Ash	0·17	0·066	10·13

Analysis No. I was of coke from crude oil, and No. II of coke from tar distillate.

The carbon was completely burned from another portion of the coke, No. II, and the weight of the ash ascertained. Since the quantity of the crude oil corresponding to the coke is ten times the coke from this determination, the percentage of ash in the crude oil may be taken as 0·0066. An examination of the ash showed that it was composed chiefly of calcic and magnesic oxides. It is interesting to note the presence of magnesic oxide in considerable quantities, indicating its dolomitic origin.

It is practically impossible to distill the Canadian oil in the ordinary method on a small scale, unless it is nearly free from water, and the water can only be completely removed by long standing with large quantities of calcic chloride. After the first distillation there is less difficulty in removing water except in the higher distillates. The necessity of vacuum distillation to avoid decomposition was even more evident in Canadian than in Ohio oil. In quantities of twelve liters each, 64·5 kilos were distilled in a porcelain still under a tension of fifty millimeters, and the following quantities of the distillates were collected at different temperatures:

	–100°	100°–150°	150°–200°	200°–250°	250°–300°	300°–350°	Residue
Grams . .	3870	7288	7159	8578	7869	6698	22059
Per cent.	6·00	11·3	11·1	13·3	12·2	10·4	34·2
					250°–350°		
Per cent. in Ohio oil.	18·6	19·8	15·1	18·0	6·2		20·9

The differences in the weights collected at different temperatures in Canadian and Ohio petroleum confirm the marked variation in composition already referred to. An explanation must evidently be sought in the larger quantities of the series C_nH_{2n+2} in the fractions below 150° from Ohio oil, and the greater quantity of the heavier oils of the series C_nH_{2n} and similar series in the portions above this point from the Canadian oil.

The percentages of sulphur in these distillates were also determined:

	–100°	100°–150°	150°–200°	200°–250°	250°–300°	300°–350°	Residue
Per cent. of Sulphur	0·25	0·45	0·47	0·75	0·78	0·81	0·83

When distilled without much decomposition, the sulphur compounds in the Canadian oil collect in smaller quantities in the lower distillates than is the case in the Ohio oil.

The distillates collected *in vacuo* showed but slight indications of decomposition; they were only slightly discolored, except the residue, above 350°, which had apparently undergone but little decomposition. The distillates above 150° and the residue above 350° are reserved for future study.

The vacuum distillate below 150° was fractioned twelve times, collecting at first within 5° then within 2° and finally within 1° limits, with the aid of a Warren condenser with glass coils and of Hempel columns. At the end of the eighth distillation eight grams collected below 55°. Of the portion between 55° and 60°, fifteen grams distilled constant at 60°–61°, barometer 741 millimeters, and a vapor density of the latter product gave 2·996; required for isohexane, 2·98.

At 67°–68°, after the twelfth distillation, ten grams of oil collected, which gave a vapor density of 3·01; required for hexane, 2·08. The distillates 75°–85° will be considered with the aromatic series. At the end of the fifteenth distillation, 20 grams distilled constant at 90°–91°, barometer 740 millimeters, and a vapor density determination of this product gave 3·50; isoheptane, C_7H_{14}, requires 3·46.

At 96°·5–97°·5, after the seventeenth distillation, barometer 740 millimeters, 80 grams collected that distilled constant within these limits, and its vapor density was found to be 3·63; required for heptane, 3·46. The composition of this oil was further established by analysis:

0·1870 gram of the oil gave 0·5781 gram CO_2 and 0·2514 gram H_2O.

	Required for C_7H_{16}.	*Found.*
C	84·00	84·31
H	16·00	15·77

Below 105°, the distillates were not in sufficient quantity to indicate definite compounds. The fractions containing toluol will be described later.

After long distillation, a fraction weighing 90 grams col-

lected constant at 118°–119°·5, with a vapor density of 4·02; required for octane, C_8H_{16}, 3·94. This fraction was purified with much care, in the same manner as the corresponding distillate from Ohio oil, and a combustion gave the following percentages of carbon and hydrogen:

(1) 0·2013 gram of the oil gave 0·6226 gram CO_2 and 0·2738 gram H_2O.

(2) 0·2036 gram of the oil gave 0·6318 gram CO_2 and 0·2799 gram $_2O$.

(3) 0·2045 gram of the oil gave 0·6324 gram CO_2 and 0·2762 gram H_2O.

	Required for C_8H_{18}	Found. 1	2	3
C	84·20	84·35	84·61	84·33
H	15·79	15·12	15·28	15·01

The low percentages of hydrogen indicated the presence still of a small quantity of the hydrocarbon containing less hydrogen, perhaps, of a series C_nH_{2n}, although the main constituent seemed to be a member of the series C_nH_{2n+2}. For further purification, another portion of the same fraction was boiled for a long time with a mixture of nitric and sulphuric acids, and with sodium as long as a solid substance was formed, and until no colored residue was left after distillation. A combustion then gave 83·90 per cent. of carbon, and 16·10 per cent. of hydrogen, showing that the oil was then practically pure octane. This fraction is receiving careful attention with reference to the action of chlorine and the formation of its derivatives.

Between 120° and 128°, the distillates collected with some persistence, as shown by the following weights after the eleventh distillation:

	120°–121°	121°–122°	122°–123°	123°–124°	124°–125°	125°–126°	126–127°	127°–128°
Grams	85	70	80	60	30	30	70	60

The weights between 120° and 124° seemed to indicate the presence of definite bodies which should require larger quantities of the oils for longer distillation and study of their behavior toward chemical reagents. One hundred and ten grams collected after the twelfth distillation at 126°–128°, barometer 758 millimeters, and after careful purification in

the manner already described, the result of the vapor density determination corresponded to octane; found 4·24, required 3·95. The accumulation of such a large quantity of product within these limits shows the necessity of further examination of the distillate containing octanes. The fractions collected at 130°–142°, containing the xylols, will be considered later. At 145°–146°, after the twentieth distillation, fractions collected with much persistence near 145°, which evidently require further study to determine whether this indicates the presence of a definite compound:

	142°–143°	143°–144°	144°–145°	145°–146°	146°–147°	147°–148°
Grams	30	32	50	75	25	22

At the end of the tenth distillation, 160 grams collected at 149°–152°, of which a large portion distilled constant at 150°–151°, barometer 749 millimeters, and gave a vapor density required for nonane; found 4·56; required for C_9H_{20}, 4·43. Distillation of the portions above 160° will be continued. The results thus far obtained indicate that the series C_nH_{2n+2} is represented by the same hydrocarbons in the Canadian oil as have been found in Ohio and Pennsylvania oils, but the lower members of the series are evidently present in much smaller proportions than in either of the other oils. This should be understood to apply to oil from the Petrolia field. As elsewhere shown (*Proc. Amer. Acad.*, current volume), the oil from Oil Springs contains much more of the volatile constituents.

AROMATIC SERIES.

Series C_nH_{2n-6}.

Benzol.—In separating the members of the aromatic series, after the eighth distillation, 20 grams collected at 77°–79°, 15 grams at 79°–81°, and 30 grams at 81°–83°. These fractions were treated with nitric acid in the manner already described for the formation of nitrobenzol, distilling off the hydrocarbons not affected by the acid. The first fraction gave 2·8 per cent. of benzol, the second 4·4, and the third 4·14 per cent. This quantity of benzol corresponds, in the total weight of the fractions, to 3 grams, representing 0·0047 per cent. in the 64·5 kilos of crude oil first distilled. Scarcely

any benzol was found in the higher and lower fractions; the percentage is, perhaps, somewhat higher than is here represented, although considerably less than the amount contained in the Ohio oil. The nitrobenzol was recognized by conversion into aniline, which gave its characteristic reaction with furfurol.

Toluol.—After the eighth distillation the distillate between 107° and 109° amounted to 40 grams, at 109°–111° to 250 grams, and at 111°–113° to 50 grams. In treating these fractions for the formation of nitrotoluol, from 109°–111° a weight of nitro-product and unaffected hydrocarbon was obtained, equivalent to five per cent. of toluol from the fraction 107°–109° one per cent., and from the fraction 111°–113° one per cent., the higher and lower fractions giving no nitrotoluol. The total weight of toluol in the three fractions was, therefore, 3·4 grams, equivalent to 0·005 per cent. of the total weight of crude oil taken. As a proof of toluol the nitro-derivative was converted into toluidine, which gave characteristic color reactions.

Xylols.—As already explained, Schorlemmer obtained indications of the presence of benzol and its homologues in Canadian petroleum, and separated cumol in the form of the trinitro-derivative. Between 126°–143°, after the twentieth distillation, the following weights were obtained:

136°–137°	137°–138°	138°–139°	139°–140°	140°–141°	141°–142°	142°–143°
30	40	25	40	25	47	30

On account of the close proximity of the xylols in boiling points it would require longer distillation with large quantities of the oils to separate them completely. We, therefore, depended upon the formation of derivatives with properties sufficiently well characterized for conclusions concerning the xylols from which they were formed. In the fraction 137°–138°, p-xylol was tested for by heating a portion of the oil with nitric and sulphuric acid. The oil deposited, on standing, a crystalline product, which, after crystallization from alcohol, melted at 139°–140°, therefore corresponding to trinitro-p-xylol. After oxidation of another portion of the same oil with chromic acid, the solution was extracted with ether and the ether evaporated; the white powder that remained

sublimed without melting, and resembled, in its appearance and properties, terephthalic acid. The quantity of p-xylol was determined according to the method suggested by Levinstein, which consists in shaking the oil thirty minutes with concentrated sulphuric acid and noting the decrease in volume. The loss in volume corresponded to 10·77 per cent., representing other aromatic hydrocarbons. The oil remaining was then agitated with fuming sulphuric acid to dissolve p-xylol, the diminution in volume representing 9·02 per cent. In fraction 139°–140° m-xylol was determined by treating a portion of the oil with dilute nitric acid washing with caustic soda and distilling with steam, which carries over the m-xylol (Brüeckner, *Ber.*, **9**, 405). The loss in volume, 7·5 per cent., was noted, and the distillate agitated with concentrated sulphuric acid; the last diminution of volume represented 8·8 per cent. of metaxylol. In attempting to determine the presence of orthoxylol, and following closely methods which have been suggested for detecting this body in presence of the meta- and the para-compounds, the nitro-products and sulphonic acids separated resembled so closely the meta-derivatives that no conclusions could be reached as to orthoxylol. Evidently much larger quantities of these distillates and special methods of separation will be necessary.

Referring the weights of the xylol-nitro-products through the weights of the fractions to the original weight of crude oil, the quantity of paraxylol is 0·006 per cent., of metaxylol 0·005 per cent. Through the formation of sodium xylolsulphonate 0·009 per cent. of xylol was found in fraction 142°–143°, which should apparently be referred to the quantity of metaxylol. Evidently these results can be accepted as represented, only approximately the quantities of the xylols, but they doubtless represent the comparative quantities in the two oils under consideration. In the distillates between 130° and 140° there were indications of other aromatic hydrocarbons capable of forming nitro-products, but larger quantities of the oils will be needed for their separation.

SERIES C_nH_{2n}.

In examining the fraction 68°–69°, collected after the twelfth distillation, for hexahydrobenzol, it was carefully purified with alcoholic mercuric chloride, nitric acid, sulphuric acid, and boiling with sodium. A combustion then gave percentages of carbon and hydrogen required for hexane: carbon 83·45, required 83·71; hydrogen 15·99, required 16·28.

The fraction 97°–98° was purified in a similar manner, except with a mixture of nitric and sulphuric acids, which gave a nitro-compound heavier than water, equivalent to ten per cent. of the original oil. This nitro-compound dissolved readily in sodic hydrate with a red color and reprecipitated with acids. The purified oil gave percentages of carbon and hydrogen required for heptane: carbon 84·31, required 84·00; hydrogen 15·77, required 16·00.

This distillate, therefore, consisted chiefly of heptane, and it contained no hexahydrotoluol.

Hexahydroisoxylol, C_8H_{16}.—After treating with concentrated nitric and sulphuric acids the fraction 118°–119° of the sixteenth distillation, the acid was considerably colored from decomposition, and, on cooling, crystals formed, which were sparingly soluble in cold alcohol. When purified from hot alcohol this substance melted at 178°, the melting point of trinitroisoxylol. Hexahydroisoxylol was therefore present in this distillate, although only in small quantity. Determinations of carbon and hydrogen seemed to indicate still a small quantity of the hexahydro-compound, as shown by the low percentage of hydrogen, yet the principal constituent evidently belongs to the series C_nH_{2n+2}:

	Required for.		Found.		
	C_8H_{18}	C_8H_{16}	1.	2.	3.
C . . .	84·20	85·71	84·35	84·61	84·33
H . .	15·79	14·28	15·12	15·28	15·01

That this distillate consisted chiefly of octane was shown by the percentages of carbon and hydrogen after the thorough treatment with acids and sodium already described: carbon, 83·90; hydrogen, 16·10.

The larger percentage of hydrogen, now sufficiently close

to the composition required for C_8H_{18} showed that the hexahydroisoxylol had been removed.

Hexahydromesitylene has been identified in Caucasus petroleum by Markownikoff and Ogloblin (*Ber. der deutsch. chem. Gesellsch.*, **16**, 1873), and it is quite possible that it is also present in Canadian petroleum. We shall submit larger quantities of the distillates between 135° and 140° to careful examination to ascertain whether it is a constituent of Canadian oil.

The work now in progress includes an examination of the distillates between 0° and 9° for the butanes; the portions distilling between 118° and 130° for the octanes, and the portions above 150°. Work is also in progress in this laboratory on the distillates above 150° from Pennsylvania petroleum, and on petroleum from the Macksburg field, taken at different levels, including the Berea grit oil. The sulphur compounds in Ohio and Canadian oils, and the nitrogen and oxygen compounds in Ohio oil, are also receiving attention.

In the study of Ohio petroleum, I have received efficient aid from Mr. E. J. Hudson, and in the Canadian oil from Mr. W. H. King. I should also acknowledge my obligations to Messrs. W. G. King and W. O. Quayle, instructors in this laboratory, and to my assistants, Messrs. Little, Cleveland and Giessen. This work has been carried on with aid granted by the American Academy of Arts and Sciences, from the C. M. Warren Fund for chemical research.

AN APPARATUS FOR EXPERIMENTING WITH THE LAWS OF FLEXURE OF BEAMS.

BY PROF. JAMES L. GREENLEAF.

The theory of elasticity applied to the strain and stress of material is the basis of nearly all structural design.

It cannot be considered completely satisfactory, for a deeper insight into molecular physics, in certain particulars, leads investigators to feel that it is not a finality.

However, granting that it is even a crude rendering of deeper truths, the fact remains that it offers a reliable and practically satisfactory process to the engineer.

Any one who is at all sceptical regarding the truth of this theory, or has had his faith in it shaken by discussion, can readily satisfy himself of its reliability by simple experiment upon that phase of it relating to flexure. There are few instances in which the processes of the calculus, applied to physical laws, find a more pleasing and direct corroboration from practical experiment, than in the case of the flexure of beams.

The following description concerns a simple but effective apparatus that I have devised for experimentally testing certain flexure formulæ for beams under peculiar conditions of support. It was easily and cheaply made, and can be readily adapted to a wide range of conditions of support and loading of beams.

Any one who has had experience in teaching the laws of resistance of materials will appreciate the practical value of such an apparatus in the class-room. Let the student work out his formulæ in the case of restrained beams, for instance, and then check the calculation of reaction, bending moment and deflection by actual experiment. The mathematics will then cease to be a mere abstraction for him, and become a personal possession.

Such exercises are easily possible with the apparatus illustrated.

The construction will readily be understood from a study of the illustration.

The scales are laid off directly on the wood in inches and tenths, and the hundredths are estimated.

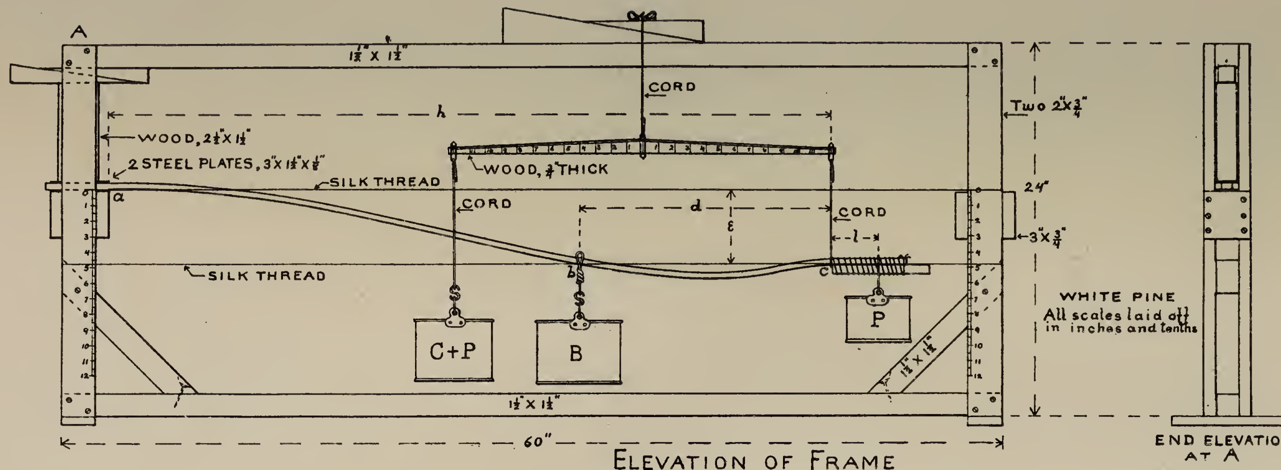
If more elaboration is desired, sliding verniers can be fitted to each of the two uprights, and the lower one of the silk threads be attached to them. Also, a small mirror can be weighted so as to hang vertically behind the threads, and then, by making the thread and its reflection coincide, the observer can insure a horizontal line of sight. In certain classes of experiments it would be more convenient to fasten a paper scale vertically on the side of the beam, and read off directly the deflection from the upper silk thread.

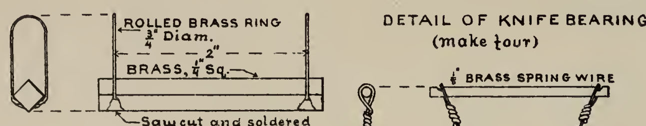
It is not at all difficult to obtain a considerable degree of sensitiveness in the apparatus, such that, with fifty pounds or more of weight in the pails, an increase of five or six of the finest bird-shot will cause a perceptible change in the deflection of the beam.

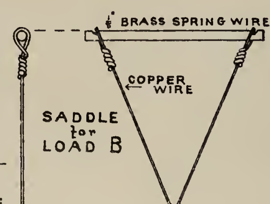
If the actual weights of the loads upon the beam are wanted, they had best be measured with a standard scale, but if simply the ratios of the loads are needed, they can be found accurately by the use of the wooden lever arm and the knife bearings.

As an example of the use of the apparatus, I will give the results of testing a beam under the conditions shown in the illustration. The beam is rigidly held at *a* by the steel plate, block and wedges, so that the tangent to the curve of deflection remains horizontal. It has a downward load at *b* and an upward one at *c*. Under the action of these two loads the beam deflects an amount, *e*. The condition is imposed that the points *b* and *c* shall be on the same horizontal line when the beam has settled down under the loads *B* and *C* (see *Fig. 2*).

Also the condition is imposed that the tangent to the curve of deflection at the end *c* shall be horizontal. This condition is readily met by first tying a short stiff strip to the end of the beam beyond *c*, so that it must remain straight beyond that point, and then hanging a load, *P*, upon it at any convenient short distance, *l*, from *c*. The amount







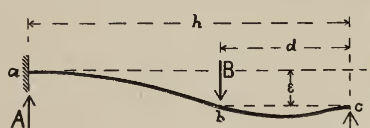


Fig. 2

FIG. 1.

APPARATUS FOR EXPERIMENTING
UPON THE
ELASTIC RESISTANCE OF BEAMS.

A large variety of experiments upon cantilevers, beams simply supported at both ends, restrained beams, and continuous beams can be made with this apparatus.

It is suitable for beams of wood or metal of moderate depth.

The weights consist of lead ingots and bird shot held in two quart tin pails.

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of P can be varied until the beam from c out occupies a horizontal line.

To give a suggestion of the practical bearing of the conditions assumed in this treatment of the beam, I may state that these are conditions to which columns in tall buildings or mill construction are sometimes subjected under wind pressure.

The formulæ applying to this case are as follows:

$A - B + C =$ zero.

$$C = \tfrac{1}{2} B \frac{(h - d)^2}{\tfrac{1}{2} h^2 - \tfrac{1}{3} h d}$$

or

$$C = \tfrac{1}{2} A \frac{(h - d)^2}{d\left(\tfrac{2}{3} h - \tfrac{1}{2} d\right)}$$

The origin of co-ordinates being taken at c and M_x denoting the bending moment at the distance x along the beam from c.

On the right of point b.

$$M_x = C\left(\tfrac{1}{3} d - x\right)$$

$$M_c = \tfrac{1}{3} C d$$

$$\frac{dy}{dx} = \frac{1}{EI} C\left(\tfrac{1}{3} x d - \tfrac{1}{2} x^2\right)$$

$$y = \frac{1}{EI} \frac{C}{6}\left(x^2 d - x^3\right)$$

On the left of point b.

$$M_x = C\left(\tfrac{1}{3} d - x\right) + B(x - d)$$

$$\frac{dy}{dx} = \frac{1}{EI}\left[(B - C)\tfrac{1}{2}(x^2 - h^2) + (B - \tfrac{1}{3} C) d (h - x)\right]$$

$$y = \frac{1}{EI}\Big[(B - C)\tfrac{1}{6}\left(x^3 - 3 h^2 (x - d)\right) +$$

$$(3B - C)\frac{d}{6}\left(- x^2 + 2h(x - d)\right) + \frac{B}{3} d^3\Big]$$

$$e = \frac{1}{EI}\left[\frac{C}{3} h (h - d)^2 - \frac{B}{3}(h - d)^3\right]$$

A comparison of figures 2 and 1 shows that the force B is represented by the weight of pail B. The upward force C at the theoretical end, c, of the beam, is represented by the weight of the pail $C + P$, minus the weight of pail P. (This is not strictly correct, but if l is made small, say one or two inches, the error can be disregarded. A correction can be entered if desired.)

In order to measure the ratio of C and B after an experiment has been made, detach the beam from the lever at c. Detach pail P from the beam, and hang it from the right hand arm of the lever at the same distance from the center as the pail $C + P$.

Then detach pail B from the beam and hang it with another knife bearing from the right-hand arm of the lever at such a distance out from the center that the system of weights suspended shall balance. (A small compensating weight equal to that of the knife bearing should be laid upon the left-hand arm of the lever at the same distance from the center on the position of load B.) Having obtained a balance the ratio of C to B equals the inverse ratio of the lever arms from the center to the loads $C + P$ and B.

As a refinement upon the above process it is important to make compensation for the weight of the beam.

This can be simply done with close approximation as follows: Before any weights are hung from the beam attach the beam to the lever at c, and hang a small weight (a small bottle loaded with shot is convenient) from the left-hand end of the lever, increasing the load until the end c of the beam is just raised to the upper silk thread.

This weight is to be retained as the compensating weight. When making an experiment on the beam place this compensating weight in pail $C + P$ as a part of the system of weights in balance. Then, when getting the ratio of C to B, and for computing the deflection remove the compensating weight from pail $C + P$.

I append a table of computed and experimental values that are extracted from the notes taken while making tests.

They show slight differences, and I believe these could

be largely reduced by exercising special care. The discrepancies in deflection are undoubtedly affected by the fact that the loads were only approximately determined in amount, although their ratios are practically precise. However, the comparatively small differences that occur in a wide range of experiments on varying ratios of *h* and *d*, with different-sized beams, and with loads varying from five to thirty pounds, show a decidedly close agreement between experiment and theory. This agreement, which is even closer in other series of experiments of a simpler nature that I have made, justifies the assertion that the theory of elasticity applied to material, within its elastic limit, unquestionably offers to the engineer a reliable and practically satisfactory process.

TABLE OF THEORETICAL AND EXPERIMENTAL DATA ON THE FLEXURE OF BEAMS SUBJECTED TO THE CONDITIONS SHOWN IN FIG. 2.

Number of Experiment.	Values of *h* and *d*. (Inches.)	Approximate Values of *B* and *C*. (Pounds.)	Ratios of *B* and *C*. Theory	Ratios of *B* and *C*. Experiment.	Ratios of *B* and *C*. Error of Experiment from Theory	Deflection *e*, in Inches. Theory	Deflection *e*, in Inches. Experiment.	Character of Beam.
5	$h = 40$ $d = 8$	$B = 14·4$ $C = 10·6$	0·738	0·730	— ·008	0·99	1·38	
6	$h = 40$ $d = 10$	$B = 8·4$ $C = 5·6$	0·675	0·651	— ·024	0·69	0·62	
7	$h = 40$ $d = 10$	$B = 15·5$ $C = 10·5$	0·675	0·650	— ·025	1·10	1·13	
8	$h = 40$ $d = 10$	$B = 28·0$ $C = 19·0$	0·675	0·634	— ·021	1·96	1·92	
9	$h = 40$ $d = 10$	$B = 17·9$ $C = 12·1$	0·675	0·655	— ·020	1·30	0·93	Seasoned white pine, 1½″ × ⅜″ section (⅜″ vert.) $E = 1,800\,000$ pounds. Compensated for weight of beam.
10	$h = 40$ $d = 15$	$B = 18·4$ $C = 9·6$	0·522	0·538	+ ·016	1·28	0·85	
11	$h = 40$ $d = 8$	$B = 25·9$ $C = 19·1$	0·738	0·714	— ·024	1·74	1·83	
12	$h = 40$ $d = 10$	$B = 7·2$ $C = 4·8$	0·675	0·668	— ·007	0·59	0·33	
13	$h = 40$ $d = 10$	$B = 21·5$ $C = 14·5$	0·675	0·658	— ·017	1·60	1·64	
14	$h = 40$ $d = 10$	$B = 7·5$ $C = 5·0$	0·675	0·651	— ·024	2·19	2·35	Seasoned white pine, ⅜″ × $\frac{25}{64}$″ section ($\frac{25}{64}$″ vert.) $E = 1,800,000$ pounds. Compensated for weight of beam.

THE THEORY OF THE AIR-LIFT PUMP.

BY ELMO G. HARRIS,
Professor of Engineering in the School of Mines of the University of Missouri.

The writer has no knowledge of any previous attempt at a mathematical analysis of the problem herein presented, except that of Professor W. H. Echols, which was read before the Philosophical Society of the University of Virginia, in 1891. Professor Echols made some interesting experiments in connection with his analysis, but unfortunately the data are not in such form as can be used in, or examined by, the formula herein obtained.

In *Engineering News*, of June 8, 1893, is an article on the "Air-Lift Pump," in which appears what seems to be a very complete account of what had been done up to that date. In that article may be found some discussion of the principles governing the action of this pump, but nothing more is established than the fact that the thing will and must act.

In this paper the writer has attempted an investigation of the principles involved, and an analysis of the action going on within the air-lift pump. The purpose of the investigation was to obtain a rational formula by which a pump could be designed intelligently, and on which experiment could be based.

It would have pleased the writer to have published with this first presentation of the subject the results of experiments testing the theory; but he has no means of carrying out such experiments.

An analysis of the action of the air-lift pump, and an investigation of the principles governing that action, can best be presented and investigated in several stages as follows:

(1) A vertical pipe, open at both ends, is partly immersed in a liquid. A quantity of gas is released within the pipe and below the surface of the liquid (*Fig. 1*). What effect will the gas have on the column of liquid; and what will be the action of the bubble of gas?

We will assume that the pipe is so large that capillary forces cannot control the action. Then the bubble will ascend. During the ascent the liquid above the bubble must pass by it in order to get below. Hence, the bubble cannot occupy the whole cross section of the pipe. In order to ascend the bubble must become elongated until the liquid can pass down. In order to pass down through the

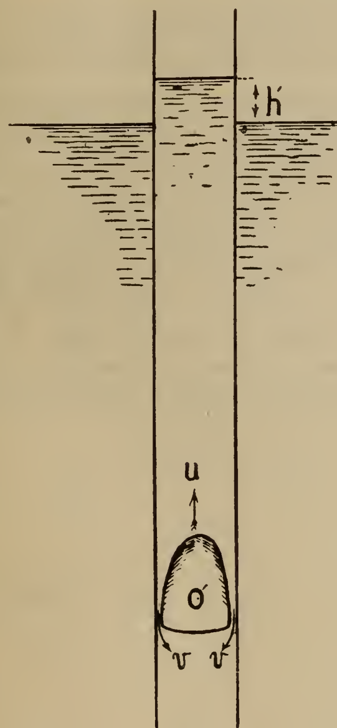

FIG. 1.

contraction formed by the bubble, the liquid must have a certain *absolute* velocity. The presence of this velocity is evidence of the existence of an unbalanced head somewhere above.

Let A = area of interior of pipe.

O' = volume of bubble, a variable.

O = volume of bubble under atmospheric pressure, a constant.

w = weight of a unit volume of water, or liquid.

Q = quantity of water passing down by bubble in a unit of time.

v = absolute velocity of water passing down by bubble.

u = absolute velocity of bubble ascending.

h' = difference of elevation of water inside and outside of pipe.

y = depth of bubble under water.

p = head of water whose pressure equals that of the atmosphere = 34 feet approximately.

To get an expression for v and h', we, apply the law of conservation of energy, remembering that the buoyancy of the bubble is a certain upward pressure amounting to $w\,O'$; that pressure exerted through distance gives work; and that, if we neglect the weight of air, there is no energy in the motion of the bubble. Then the work done by the ascending bubble must be found again in the downward motion of the water around the bubble. Considering the work done in one second, we get the following equation:

$$w\,O'\,u = w\,A\,u\,\frac{v^2}{2g}$$

or

$$\frac{O'}{A} = \frac{v^2}{2g}$$

The term

$$\frac{v^2}{2g}$$

will be recognized as the equivalent of the head h' necessary to produce v. Hence

$$h' = \frac{O'}{A}$$

and

$$v = \sqrt{2\,g\,\frac{O'}{A}}$$

The same value for h' can be gotten from an equation of pressures. Thus

$$w\,O' = w\,h'\,A,$$

or

$$h' = \frac{O'}{A}$$

but this method does not recognize the existence of motion which is necessary to a proper conception of the action of the pump.

To get an expression for the upward velocity u of the bubble, we apply the law of physics, that forces are proportional to the velocities they can produce in a given mass in a given time. The force of buoyancy $w\,O'$ of the bubble produces in one second a downward velocity v in a mass of water having the weight $w\,Q$. Hence

$$w\,O' : v :: w\,Q : g$$

or

$$Q = \frac{O'\,g}{v}$$

Now

$$u = \frac{Q}{A} = \frac{O'\,g}{v\,A}$$

but it has been proven that

$$\frac{O'}{A} = \frac{v^2}{2\,g}$$

Therefore

$$u = \frac{v}{2}$$

This being established, it follows that the bubble, at its largest cross section, occupies half the area of the pipe. (See limitation, page 45.)

The writer attempted to work out the form of the bubble under the stated condition, but, on finding some of the terms in the eighth degree, he abandoned the attempt and contented himself with observing the form and motion in a

glass tube. It is an easy and exceedingly interesting experiment, and one recommended to those interested in this subject.

The time required for a bubble to ascend from a depth D to the top of the pipe can be found as follows:

$$d\,t = \frac{d\,y}{u} = \frac{d\,y}{\sqrt{\frac{g\,O'}{2\,A}}} = \left(\frac{2\,A}{g}\right)^{\frac{1}{2}} \frac{d\,y}{(O')^{\frac{1}{2}}}$$

Now, O' varies inversely as the pressure, and the pressure varies directly as the head of water. Hence

$$O' : O :: p : p + y$$

$$\therefore\ O' = O\,\frac{p}{p+y}$$

Substituting this value of O' we get

$$d\,t = \left(\frac{2\,A}{g\,O\,p}\right)^{\frac{1}{2}} (p+y)^{\frac{1}{2}}\,d\,y$$

Integrating between the limits D and zero, we get

$$T = \frac{2}{3}\left(\frac{2\,A}{g\,O\,p}\right)^{\frac{1}{2}} \left[(p+D)^{\frac{3}{2}} - p^{\frac{3}{2}}\right]$$

If we make $g = 32$ and $p = 34$, this becomes

$$T = \sqrt{\frac{A}{O}} \left[\cdot 028\,(D+34)^{\frac{3}{2}} - 5\cdot 55\right]$$

An experimental determination of T will probably be the easiest test of the accuracy of the theory which is the basis of this paper. For reasons hereafter noted the writer recommends that in such a test the pipe be not less than six inches in diameter. Owing to friction the actual time is always longer than the computed time.

(2) Preliminary to a general investigation of the laws governing a pump operated by bubbles of air, we will take the special case illustrated by *Fig. 2*. Here the pipe terminates at the surface of the reservoir, and has only a single bubble liberated within it.

Now, in the absence of the standing head h', water will flow out at the top with a velocity v, and the rate of dis-

charge will be $A\,v$, but at the same time water will be escaping down by the bubble at the rate of

$$\frac{v\,A}{2}$$

The discharge at top is useful effect, the escape down by the bubble is lost energy. Hence it is apparent that two-

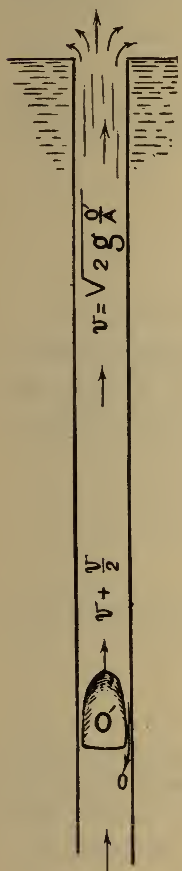

FIG. 2.

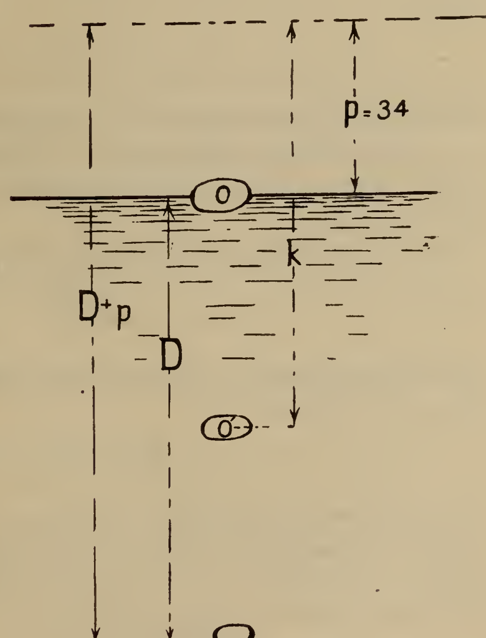

FIG. 3.

thirds of the work is utilized and one-third lost, or the efficiency is sixty-six per cent. This is interesting in itself, but it gives but little light on the practical problem. It should be carefully noted that u is now no longer absolute velocity. It is now the velocity of the bubble relative to

that of the water above or below. The downward velocity v of the water passing by the bubble is now relative also. It is really standing still at the largest cross section of the bubble.

(3) In order to proceed with the practical problem it is necessary to have an expression for the work done in forcing a given volume of air, or gas, down to a given depth under water, or other liquid. Such an expression is found as follows:

Observing the relation between volumes and pressures for a given mass of gas at constant temperature, we have (see *Fig. 3*):

$$Vol.\ O' : Vol.\ O :: p : k$$

Hence

$$O' = \frac{O\,p}{k}$$

where O is the volume at atmospheric pressure and O' its volume when submerged to a depth $k - p$, p being the liquid head equivalent to atmospheric pressure (thirty-four feet for water).

The buoyancy of the bubble O' will be

$$w\frac{O\,p}{k}$$

the work necessary to force it down through the elementary depth $d\,k$ will be

$$w\,O\,p\frac{d\,k}{k}$$

and the total work done in forcing O from the surface to a depth of emersion D, will be the integral between the limits $k\ (= D + p)$ and $k = p$. Representing by W_1 the work done in forcing down a single bubble of volume O, we have

$$W_1 = \int_{p}^{D+p} w\ O\ p\frac{d\,k}{k} = w\ O\ p\ log_e\left(\frac{D+p}{p}\right)$$

In this expression D is the static head on the bubble. Under working conditions the bubble would generally be released in a pipe in which the liquid is ascending with a cer-

tain velocity, which will be represented hereafter by V. Under these circumstances D must be replaced by

$$D - \frac{V^2}{2\,g}$$

Hence, the formula, in practical working, will generally be

$$W_1 = w\,O\,p\,\log_e\left(\frac{D. - \frac{V^2}{2\,g} + p}{p.}\right)$$

Now, if, instead of one bubble, we force down n bubbles in one second, the formula for work done per second becomes

$$W = w\,n\,O\,p\,\log_e\left(\frac{D - \frac{V^2}{2\,g} + p}{p}\right)$$

The next step is to account, mathematically, for all the work done by the n bubbles after they are released in the pipe. This will be divided into four parts, as follows:

(1) The kinetic energy in the liquid discharged at top of pipe. Call this K.

(2) The energy necessary to raise the liquid to the top of discharge pipe. Call this M.

(3) The energy lost by liquid slipping down by bubble. Call this L.

(4) The energy consumed by friction in passing through pipe. Call this F.

To get K, note that the quantity of water entering at bottom of pipe is $A\,V$, and to this is added, as it ascends the pipe, a quantity of air, which, as it escapes at atmospheric pressure, will, as it discharges, have a volume $n\,O$. Therefore, the velocity of the mixture of water and air at top of pipe will be

$$\frac{A\,V + n\,O}{A}$$

and the energy in the discharge will be

$$K = w\,A\,V\left[\frac{\left(\frac{A\,V + n\,O}{A}\right)^2}{2\,g}\right] = \frac{w\,V}{2\,g\,A}(n\,O + A\,V)^2$$

If h represent the height to which the pipe rises above the surface of the reservoir, then

$$M = w\ A\ V\ h$$

The absolutely correct formula for L is too complicated for use in practice. The writer has adopted an approximation which is sufficiently accurate for practical purposes.

It has been shown that the rate of loss of liquid from above to below one bubble is

$$v\ \frac{A}{2}$$

that is the bubble rises each second through

$$\frac{v}{2}$$

without doing useful work. This loss is always going on whether useful work is being done or not. The loss of work represented by this rise of the bubble relative to the liquid is

$$w\ O'\ \frac{v}{2}$$

per second, and if the bubble remains in the pipe for T seconds, the total loss for one bubble will be

$$w\ O'\ \frac{v}{2}\ T$$

but, since there are n bubbles passing per second the total loss in one second for the combined action will be

$$L = w\ n\ O'\ \frac{v}{2}\ T$$

If H represent the height of discharge above point of air inlet, and R represent the mean rate of ascent of a bubble, then

$$T = \frac{H}{R}$$

Now, R will be composed of two parts. First, the mean velocity of the ascending water. Second, the relative motion

$$\frac{v}{2}$$

of the bubble to the water above or below it. The volume of the bubble at top of pipe is O. At the bottom its volume is

$$\frac{O\,p}{D - \dfrac{V^2}{2\,g} + p}$$

since its volume varies inversely as the pressure. Hence, the mean volume of the $n\,O$ bubbles is

$$\frac{n\,O}{2}\left(1 + \frac{p}{D - \dfrac{V^2}{2\,g} + p}\right)$$

Therefore,

$$R = V + \frac{n\,O}{2\,A}\left(1 + \frac{p}{D - \dfrac{V^2}{2\,g} + p}\right) + \frac{v}{2}$$

Putting these values in the above expression for L it becomes

$$L = \frac{w\,n\,O'\,v\,H}{2\left[V + \dfrac{n\,O}{2\,A}\left(1 + \dfrac{p}{D - \dfrac{V^2}{2\,g} + p}\right) + \dfrac{v}{2}\right]}$$

In getting this expression O' has been treated as a constant, while in reality it varies inversely as the pressure, and therefore changes at every stage of its ascent. It must also be noted that

$$v = 8\sqrt{\frac{O'}{A}}$$

For an approximation O' will be assumed constant and equal to the mean value between top and bottom, that is

$$O' = \frac{O}{2}\left(1 + \frac{p}{D - \dfrac{V^2}{2\,g} + p}\right)$$

To simplify the formula we will put

$$\frac{p}{D - \dfrac{V^2}{2\,g} + p} = C$$

Then

$$L = \frac{w\, n\, O\, v\, H\, (1 + C)}{4\left[\, V + \dfrac{n\, O}{2\, A}\, (1 + C) + \dfrac{v}{2}\right]}$$

To establish an expression for loss from friction we will work from the accepted formula, viz.:

$$\text{Loss by friction} = w\, Q \times \text{coefficient of friction} \times \frac{\text{length of pipe} \times \text{square of velocity}}{\text{diameter of pipe} \times 2\, g}$$

in which the coefficient of friction will be taken as ·02, and the velocity will be taken as the mean already used, that is

$$V + \frac{n\, O}{2\, A}\, (1 + C)$$

Inserting these and reducing we get

$$F = w \cdot 0003\, H\, V \sqrt{A} \left[V + \frac{n\, O}{2\, A}\, (1 + C) \right]^2$$

Now, by the law of conservation of energy

$$W = K + M + L + F$$

or

$$w\, p\, n\, O \log \frac{1}{C} = \frac{w\, V}{2\, g\, A}\, (A\, V + n\, O)^2$$

$$+ w\, A\, V\, h + \frac{w\, n\, O\, v\, H\, (1 + C)}{4\left[V + \dfrac{n\, O}{2\, A}\, (1 + C) + \dfrac{v}{2}\right]}$$

$$+ w \cdot 0003\, H\, V \sqrt{A} \left[V + \frac{n\, O}{2\, A}\, (1 + C) \right]^2$$

A solution of this equation by the regular methods of algebra, would be too difficult for practice, but fortunately the conditions are such that a solution can be readily reached by a tentative method as follows: Cancel w and treat the last two terms of the second member temporarily as a constant, representing them for simplicity by $l + f$.

Now, the equation will be a quadratic in $n\ O$. Putting $g = 32$, and $p = 34$, the value of $n\ O$ becomes

$$n\ O = \pm \sqrt{\left(A\ V - \frac{1088\ A\ log\frac{1}{C}}{V}\right)^2 - \left(A^2\ V^2 + 64\ A^2\ h + \frac{64\ A\ (l + f)}{V}\right)} + \frac{1088\ A\ log\frac{1}{C}}{V} - A\ V$$

the (—) sign to be taken.

Note that in the analysis it has been necessary to consider n and O separately. Hereafter the product $n\ O$ will be treated singly.

The data from which engineers will usually have to work will be numerical values of A, D, h and V. For a first approximation to $n\ O$ when h is greater than one-tenth of D, l may be taken as $\frac{1}{3}$ $(A\ V\ h)$ and f not less than $\cdot 0003\ H\ V^3 \sqrt{A}$. Insert these in the formula and solve for an approximate value of $n\ O$; insert this in the expressions for l and f and take out more accurate values of l and f; with these work out more accurate value of $n\ O$, etc. The second or third approximation will be found sufficiently close. Indeed, except for experimental investigation the first will generally suffice.

In computing l, v must be taken equal to

$$8\sqrt{\frac{O'}{A}}$$

O' will be difficult to measure and to control. If

$$O' = \frac{A}{4}$$

then $v = 4$, which would probably make a good working condition.

If the problem should be a given value of $n\ O$ from which to get V, it would be practically indeterminate except from a table giving values of $n\ O$ and V for all practical values of $A\ h$ and D.

RECAPITULATION.

Let A = area of pipe.

D = depth of immersion of point where air is admitted.

h = height of point of discharge above free surface of water.

$H = D + h$.

O = volume of a single bubble at atmospheric pressure.

n = number of bubbles admitted per second.

V = velocity of water in pipe below point of air admission.

$v = 8\sqrt{\frac{O'}{A}}$, (may be taken as 4 until more definitely determined by experiment).

$$C = \frac{34}{D - \frac{V^2}{2g} + 34}$$

$log \frac{1}{C}$ = Naperian (or hyperbolic) logarithm of $\frac{1}{C}$

= common logarithm of $\frac{1}{C} \times 2{\cdot}3$ approximately.

$$l = \frac{n\,O\,v\,H\,(1 + C)}{4\left[V + \frac{n\,O}{2\,A}(1 + C) + \frac{v}{2}\right]}$$

$$f = 0{\cdot}0003\;H\;V\sqrt{A}\left[V + \frac{n\,O}{2\,A}(1 + C)\right]^2$$

$$n\,O = -\sqrt{\left(A\;V - \frac{1088\;A\;log\frac{1}{C}}{V}\right)^2 - \left[A^2\,V^2 + 64\,A^2\,h + \frac{64\,A\,(l + f)}{V}\right]} + \frac{1088\;A\;log\frac{1}{C}}{V} - A\;V \;\;.\;.\;.\;.\;.\;.\;.\;.\;.\;\; \text{(III)}$$

$W =$ work delivered per second in foot pounds

$$= w\, n\, O\, p \log \frac{1}{C} = 2116\, n\, O \log \frac{1}{C}$$

$$E = \text{efficiency} = \frac{h\, A\, V}{34\, n\, O \log \frac{1}{C}}$$

In order that equation (III) may be thoroughly understood and intelligently used, the following discussion is essential:

(1) The equation ceases to apply when $A\, V = n\, O$. For, on the assumption that the bubble occupies one-half of the area of the pipe, there would, at this limit, be a continuous column of air and a continuous column of water, each occupying half the area of the pipe—a condition obviously absurd. If h be taken as zero in equation (III), the roots become imaginary when $A\, V = n\, O$. In practice the limit will be reached sooner. After the limit is reached the outflow will probably become intermittent and the pressure in the air receiver irregular.

(2) Concerning the size of the bubble:

The law established on page 35 will not hold, or rather it gives way to another, when the size of the bubble is so small that the surface tension in the liquid, which tends to compress the bubble into a sphere, becomes stronger than those forces tending to draw it out until its area of cross section is one-half that of the pipe. By examining the expression for loss of work due to slip,

$$L = \frac{w\, n\, O\, v\, H\,(1 + C)}{4\left[V + \frac{n\, O}{2\, A}(1 + C) + \frac{v}{2}\right]}$$

it will be seen that this loss varies almost directly as v, and since

$$v = 8\sqrt{\frac{O'}{A}}$$

we must decrease O' in order to decrease L, until the limit is reached below which O' will not occupy half the area of the pipe. The effect of bringing the bubble below this

limit will probably be a loss of energy caused by whirls and contortions of the bubble which must create irregular currents and vortices within the pipe—such action as we always see when a bubble rises in a pond or large vessel. When the bubble is confined in a pipe of proper dimensions, its motion is perfectly regular. The writer ventures to pre-

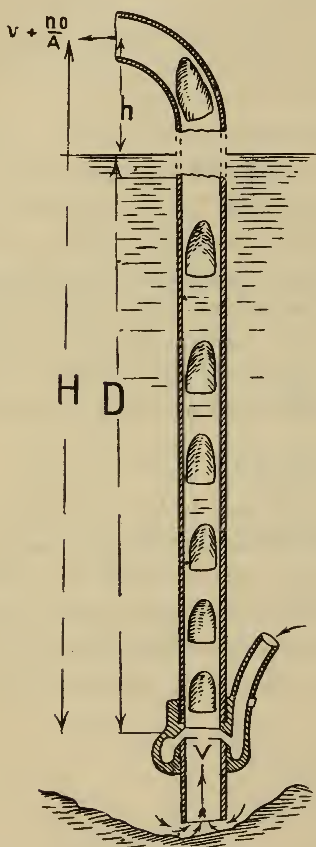

FIG. 4.

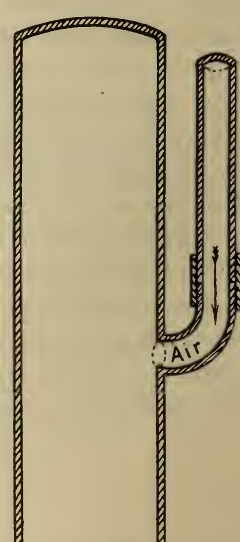

FIG. 5.

dict that the best results will be had when the volume of the individual bubble is just large enough to occupy half the area of the pipe. An expression for this volume in terms of the area of the pipe has not been found. It will be difficult to establish either by calculation or by experiment.

On the other hand, as the bubble increases, there seems

to be no limit if the bubble is allowed time to adjust itself to the forces about it, unless an exception be made of the case of a comparatively large bubble in a small pipe. Here surface tension tends to compress the bubble to a sphere, thereby causing it to fill more than half the area of the pipe.

(3) The loss due to friction is in no way peculiar to this method of raising liquid, and, if we wish to investigate results exclusive of friction, f can be omitted. The loss is known to vary approximately as the square of the velocity. The only way to reduce this loss is to use as large and as smooth a pipe as possible.

In the writer's opinion the apparatus best suited for carrying out the principles set forth in this article should be about as shown in *Fig. 5* or *Fig. 6*. *Fig. 5* shows the simplest conceivable form, and needs no explanation. *Fig. 6* would be more durable. It has also the advantage of being adjustable, the piece n being arranged to screw in or out, thereby closing or opening the circular slot through which air escapes. In both these designs the one great advantage of this style of pump is carefully guarded; that is, that it can act without an obstruction or contraction anywhere within the main pipe. It is by virtue of this that the pump is entitled to, and will hold, a place in the future. By this it is pre-eminently suited for a great variety of dredging processes. The writer first undertook this investigation with the intention of utilizing the device in the various dredging operations necessary in connection with the laying of submerged foundations. Suspended to a derrick and having a flexible air pipe, the air lift pump can be readily applied anywhere within the field of the derrick, and in very contracted spaces. For similar reasons it may be applied with advantage in placer mining in rivers and lakes. As a means of lifting sewage it seems to have everything in its favor. It has already been applied with good results for producing or increasing the flow from deep wells. It has also found a good field in elevating corrosive chemicals and hot liquids.

As a pump for raising liquid to great heights it will not be a success, for, in order to get good results, the depth of submersion must be greater than the lift.

In all that has preceded, it has been supposed that the air enters the pipe above its lower extremity, and without obstructing the pipe, as illustrated by *Figs. 5* and *6.* Hence the formulæ here given are inapplicable to some of the designs now in use. For instance, *Fig. 7* shows the design used at De Kalb, Ill.* Here the obstructions in the main pipe are very serious. There seems to be no good reason for attaching a reducer to the air pipe, nor for turning the nozzle up. Better results would probably have been gotten if both had been omitted.

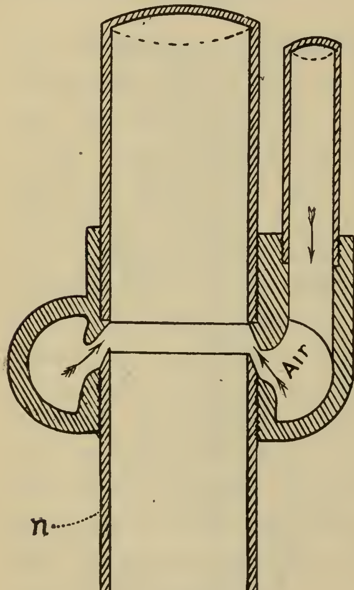

FIG. 6.

FIG. 7.

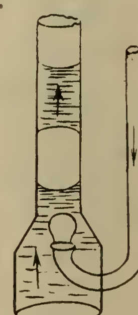

FIG. 8.

Fig. 8 is taken from a current advertisement of an air-lift pump. Here the air is released in a funnel attached to the lower end of the pipe. To this case the formulæ cannot apply unless we know what velocity exists in the water at the point where the air escapes. If this can be determined, the formula for work can be modified accordingly.

If the air escapes in still water, and then rises into the pipe, the formula will be simply

$$W = w\,n\,O\,p\,log_e\left(\frac{D+p}{p}\right)$$

* See *Engineering News*, July 12, 1894.

Two patents have been granted by the United States, each, it is presumed, intended to cover the whole field of the air-lift pump.

In the first or older patent occurs the following claim:

"In the art of elevating water, the method of causing a column of water to ascend in a conductor by the weight of the external water, which consists of introducing a tube of the desired length at the required depth into the water to be elevated, and then injecting compressed air in the form of minute bubbles into the water at the lower end of the tube, thereby aërating the water, whereby a continuous stream is caused to flow upward to the point of discharge."

In a later patent the following is the first and chief claim:

"As an improvement in the art of elevating liquid, the process which consists in submerging a portion of an open-ended eduction pipe in the body of the liquid to be raised, and continuously introducing into the liquid within the lower part of the pipe a series of bubbles of a compressed gaseous fluid, containing enough of the fluid to expand immediately across the pipe and fill the same from side to side, forming pipe-fitting piston-like layers at or just above the point of their entrance into the pipe, whereby the column of liquid rises in the pipe after the forcing out of the liquid first standing in the latter is subdivided by the gaseous fluid into small portions before it reaches the level of the liquid outside of the pipe, and a continuously upward-flowing series of well-defined alternate layers of gaseous fluid and short layers of liquid is formed and forced up the pipe."

It will be seen that the first claim falls short of the best proportion for the bubbles, while the second overleaps it. The writer does not think the conditions set forth in the second claim can be realized except in small tubes under the condition pointed out on pages 45 *et seq.* Should this condition be found to hold in practice, l would be zero in equation (III). Otherwise the discussion would in no way be changed.

The slip of the bubble is capable of accurate determina-

tion by experiment as follows:* Cause the pipe to extend above the water so far that there will be no discharge of water. Then the loss from slip of the bubble must equal the work done or $L = W$. In equation (II) it will be remembered that we assumed the "slip" u to be

$$\frac{v}{2}$$

If then in (II) we put u for

$$\frac{v}{2},$$

and $V =$ zero, and equate it to W, we will get

$$\frac{w\,n\,O\,u\,H\,(1 + C)}{\frac{n\,O}{A}\,(1 + C) + 2\,u} = w\,n\,O\,p\,\log\frac{1}{C}$$

Whence

$$u = \frac{n\,O\,p\,\log\frac{1}{C}}{A\left[H\,(1 + C) - 2\,p\,\log\frac{1}{C}\right]}$$

In the experiment, $n\,O$ and H will be measured, and C computed. Thus determined, u becomes an experimental coefficient, and the expression for l will be

$$l = \frac{n\,O\,u\,H\,(1 + C)}{\frac{n\,O}{A}\,(1 + C) + 2u}$$

The writer recommends that experiment be first directed along this line, and afterward to the determination of $(l + f)$, as a single experimental coefficient, from the equation

$$(f + l) = n\,O\,p\,\log\frac{1}{C} - \frac{V}{2\,g\,A}\,(n\,O + A\,V)^2 - A\,V\,h$$

From data collected by the writer there seems no doubt that such pumps have been operated when the discharge of air exceeded the discharge of water, that is when $n\,O$ exceeded $A\,V$, but in all these cases the pipe was small or obstructed, and the data were indefinite.

* Suggested by Professor Echols in the paper already referred to.

The pressure of air necessary to start a pump is greater than that necessary to keep it in action when once started. That it must be so is clear when we reflect that the pressure in still water at a depth D is $w\,D$, but if the water be moving with a velocity V, the pressure is

$$w\left(D-\frac{V^2}{2g}\right)$$

Hence, the instant the discharge commences the pressure in the receiver will be reduced. This principle also accounts for the intermittent action which occurs under certain circumstances: Until a current is created, every bubble entering the pipe is under a pressure of $w\,D$; but the instant the discharge commences the pressure drops to

$$w\left(D-\frac{V^2}{2g}\right)$$

and all bubbles in the pipe expand suddenly, causing a mild degree of explosion which may nearly empty the discharge pipe, thereby bringing the pressure on the air inlet orifice below

$$w\left(D-\frac{V^2}{2g}\right)$$

which is the pressure needed to maintain continued action, too much of the compressed air will escape, and, when the violent action is over, the store of compressed air will be practically exhausted and the water will have an opportunity to regain its full static head D against the escape of air. This completes one period of the action.

To prevent intermittent action the escape of air into the discharge pipe must be controlled. It should be throttled the instant the discharge of water commences. That intermittent action does not always occur is probably due to the effect of friction in the pipe conducting air to the point of admission. As this friction increases with the square of the velocity, it is evident that in long pipes of small cross section it will serve to some extent as a governor, tending to control the discharge of air.

The tables below show results by equation (III). In tables 1 to 6 inclusive, f has been purposely neglected in order to show the results of conditions peculiar to this kind of pump.

	h	l	f	$n\ O$	E	
Table 1. $A = \frac{1}{2}$, $D = 20$, $v = 2$, $V = 4$, $C = ·63$	0	0·26	—	0·05	—	
	4	2·2	—	0·71	0·72	
	10	5·3	—	1·73	0·74	
Table 2. $A = \frac{1}{2}$, $D = 20$, $v = 4$, $V = 8$, $C =$	0					
	4					
	10					
Table 3. $A = \frac{1}{2}$, $D = 100$, $v = 2$ *, $V = 4$, $C = 0·25$	0	1·0	—	0·08	—	
	4	3·0	—	0·27	0·64	
	32	23·8	—	1·95	0·70	
Table 4. $A = \frac{1}{2}$, $D = 100$, $v = 2$ *, $V = 16$, $C = 0·26$	0	3·6	—	0·96	—	
	4	7·0	—	1·94	0·36	
	32	28·9	—	9·68	0·68	$n\ O > A\ V$ ∴ out of limit.
Table 5. $A = 1$, $D = 100$, $v = 2$, $V = 4$, $C = 0·254$	0	4·42	—	0·29	—	
	4	6·10	—	0·54	0·63	
	32	36·44	—	3·66	0·75	
Table 6. $A = 1$, $D = 100$, $v = 2$, $V = 16$, $C = 0·261$	0	6·60	—	1·68	—	
	4	11·33	—	3·33	0·42	
	32	72·00	—	16·91	0·66	$n\ O > A\ V$

	h	l	f	$n\ O$	E	
Table 7. $A = 0·196$ ($d_1 = 3''$), $D = 100$, $v = 4$, $V = 4$, $C = 0·246$	0	0·6	0·8	0·03	—	
	4	3·2	1·0	0·16	0·42	
	8	5·3	1·27	0·28	0·47	
	16	9·42	1·74	0·52	0·52	
	23					
Table 8. $A = 0·196$, $D = 100$, $v = 4$, $V = 8$, $C = 0·255$	0	3·26	7·92	0·30	—	
	4	6·74	10·40	0·59	0·24	
	8	9·19	12·55	0·86	0·33	
Table 9. $A = 1$, $D = 40$, $v = 4$, $V = 4$, $C = 0·46$	0	1·71	1·80	0·18	—	
	4	11·29	2·49	1·20	0·50	
	10	25·20	3·86	2·74	0·55	
	13					

CELLULOSE PROTECTION FOR WAR VESSELS AND FOR THE MERCHANT MARINE.*

By B. P. Wiltberger.

While it has been proved that the present system of subdivision into a number of water-tight compartments, which has been adopted by all the large steamship lines, is a great step towards security, there are occasional instances where large vessels have been sunk notwithstanding this precaution. Absolute buoyancy can only be attained by cellulose protection, and, in the near future, all passenger steamers will be obliged to follow the path adopted by our men-of-war in that direction.

If, by means of a wall or belt of cellulose, protection is insured against the devastating effect of an explosive projectile passing entirely through the belt, how much stronger may be our faith that this same protection will be efficient, when, instead of such an engine of destruction, we have only to withstand the shock of wreckage, or rocks, or icebergs which smash, crack or break, but do not pass entirely through?

There are navigation laws requiring vessels to provide themselves with signals, fog horns, and the most powerful steering gear, to reduce speed and to follow the rules of the road in fog and storm. But, whether or not they conform to these requirements, the steamers provided with cellulose (in virtue of their absolute unsinkability) will have nothing to fear from the blows received from other vessels, from reefs forgotten by the chart-makers, or from icebergs so prevalent at certain seasons of the year.

Our government has adopted the cellulose system on all its latest warships, and it is said to be the intention of the Navy Department to coffer-dam *all* the warships with cellulose in the near future.

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* Abstract of a paper read at the stated meeting of the Institute, February 20, 1895.

Another new invention, by which leaks in vessels can instantly and permanently be closed, is the apparatus called "Colomes Leak Arrester." This invention I purpose now to show you in operation, and will be clearly explained by

FIG. 1.—Position of man in the act of inserting the arrester. A jagged hole four inches in diameter, with a water pressure of four feet.

the accompanying pictures. You will observe how easily the apparatus can be handled by reason of its lightness, and how quickly it can be applied.

The moral effect of having so simple a means of stopping leaks on board a vessel makes it imperative upon those

responsible for the lives of passengers to investigate this new system in which cellulose (from its yielding nature and wonderful qualities of filling up any sinuosity, burred or jagged parts of the orifice) plays a most important rôle.

FIG. 2.—The pick end has just fallen across the hole, and the inflow of water is partially checked. The man is placing the cellulose bag, washer and nut at the same time, and can now work without getting wet.

The striking results of previous experiments made, have induced the United States, France, and other governments, to include these leak arresters in the lists of outfits for their men-of-war.

SANITARY ENGINEERING.

By Wm. Paul Gerhard, C.E., Consulting Engineer for Sanitary Works; Mem. Amer. Public Health Association; Amer. Forestry Association; German Samaritan Society; Corresp. Mem. Amer. Inst. of Architects; Honorary Consulting Sanitary Engineer to the Department of Health of the City of Brooklyn, N. Y., etc.

Continued from vol. cxxxix, p. 475.

STREET PAVEMENTS.

All roads and streets serve for purposes of intercommunication and traffic; city streets, however, are planned with the further object of providing light and air to the adjacent houses, and, incidentally, are utilized as receptacles for a network of underground pipes, conduits and wires which afford drainage and sewerage facilities and furnish water, gas, heat, light, steam and electric power, etc., to the buildings. When we demand—even of our country roads—that they should not be dusty in dry weather, nor muddy and impassable in wet seasons, it is obvious that city streets, in which our habitations, offices and places of work are located, should be subject to much stricter requirements. We are, as far as this paper is concerned, interested chiefly in the sanitary aspects of street construction or the paving of its surface. The essential requirements of a good city street pavement are quick surface drainage, good foundations, impermeability and hardness of surface, avoidance of slipperiness, least resistance to traffic, cleanliness and noiselessness. Impermeability and noiselessness are the chief desiderata, from a sanitary point of view. There is plenty of medical testimony available tending to prove that the ceaseless noise, from early morning till late at night, due to vehicles passing over rough stone pavements, affects the nervous system and reduces the duration of life.

A street surface should be as water-tight as possible, to prevent a downward soakage into the ground of liquids, or the retention of filth in the joints and cracks of the paving stones. The street surface should drain off quickly, and

there must be no depressions or inequalities where water can stagnate and become offensive. A street pavement should not be slippery, as this not only causes horses to fall, but is equally dangerous to life and limb of pedestrians. Cleanliness of pavements is essential to prevent dangerous exhalations and illness due to polluted air. Finally, paved streets should be noiseless, for the continuous jarring and rumbling of heavy vehicles, the shaking of the foundations and the accompanying vibrations of window panes, doubtless affect the nerves of town-dwellers, disturb sleep, aggravate the suffering and retard the recovery of the sick.

For these and similar reasons the selection and construction of a good street pavement is a sanitary problem of much importance. Leaving out of consideration some kind of pavements which are not used to any great extent, the choice lies between macadam, wood, cobblestone, granite block and asphalt pavements.

Macadamized roads are not well suited for city pavements. Under a heavy street traffic the broken stones—particularly if the softer limestones are used—are quickly ground to powder, causing clouds of disease-breeding and irritating dust in dry weather, while in wet weather the dust is quickly changed into the worst kind of soft mud. The surface of macadamized roads wears out very quickly, and almost the only advantages worth mentioning are that such roads are noiseless, and that they afford a firm footing for horses.

Wooden pavements have formerly been employed, to a large extent, in American cities, but, of recent years, they have been given up, partly, no doubt, on account of the growing scarcity of timber, due to the barbarous destruction of our forests. From a hygienic point of view, wooden pavements, unless the blocks are impregnated to prevent decay, offer several important objections. In the first place, wood absorbs not only dampness, but likewise putrefying matter, and exhales bad odors, and, being alternately wet and dry, the surface soon rots. It is a well-known fact that decaying wood is detrimental to health. Wooden pavements, on account of their elasticity, are more noiseless

than stone pavements, but they are expensive to maintain, and soon their surface becomes quite unequal, except when the precaution is taken to lay the blocks on a concrete or sand foundation.

Cobblestone pavements are of a very inferior character, on account of the uneven surface, due to absence of proper foundation and the rough joints and numerous pockets, due to the irregularity of the stones. The joints of such pavements soon fill up with putrefying street filth and create obnoxious odors. Such pavements are very difficult to maintain in a clean condition, and, taken altogether, they are unfit for the thoroughfares of large cities.

Granite pavement, if composed of stones of regular size, evenly laid, well bedded on a good concrete foundation, and with the joints carefully filled with sand or cement, or tar and gravel, is a good city pavement for heavy traffic. The stone blocks should not be too hard, as they otherwise become quite slippery from abrasion, and the evenness of the pavement is usually disturbed by the frequent tearing up required for underground pipe connections. The improved stone pavements, with well-filled joints, have the one disadvantage of causing increased vibration of buildings.

The best pavement, from a sanitary point of view, is, without doubt, the asphalt pavement, and it is destined to become the favorite pavement for streets with light traffic. It is water-tight and quite impermeable; it prevents soakage into the subsoil; it is free from the noxious odors so often found on pavements with joints; it is durable, smooth, and very readily cleaned; it renders all traffic noiseless, does not cause jarring or vibration of buildings, and creates no dust due to abrasion and wear. About its only disadvantage is its liability to become slippery when the pavement is damp or greasy, as during foggy weather, or where soft mud is carried to it from adjoining stone pavements, by horses' hoofs, pedestrians' shoes and carriage wheels. It is principally adapted to the residential parts of cities, where there is no heavy traffic; owing to its noiselessness it is also preferred in the neighborhood of courthouses, schools, hospitals, etc.

Other durable pavements are the vitrified paving blocks, the asphalt blocks and brick pavements, in the laying of which particular care should be given to the filling in of the joint spaces.

Footpaths and sidewalks are paved with flagstones, or with artificial stone, with bricks laid flat, or with asphalt, and these should also be laid so as to afford good drainage into the gutters, and must be constructed so as not to become slippery. Gutters must be constructed with care, to avoid leakage of storm-water into the subsoil and the cellars of houses.

I have already alluded to the fact that city streets serve also the purpose of receptacles for many pipe conduits. In our large cities the number of different pipe lines buried under the street surface is constantly growing. We have not only one or several street water mains, gas mains, sometimes separate mains for fuel gas and lighting gas, sewers for rain-water and house-wastes, and in the "separate" system two lines of sewers, but also electric light conduits, telegraph wires for commercial uses, for fire alarm system, and for police telegraph; telephone wires, pneumatic conduits for mail, parcel delivery and telegraph messages; electric or pneumatic conduits for synchronized clocks; compressed air mains, cables and trolley line wires, steam conduits, hot-water pipes, pipes for cooling purposes, and what not. At street intersections the network of pipes is particularly crowded, for here we find, in addition to the above, the sewer man-holes, the catch-basins, the shut-off valves for water and gas, and the man-holes on subways for electric and telegraph wires.

In order to avoid the endless tearing up of streets and pavements, and the incidental disturbance of traffic, caused by repairs or connections to the various conduits, it has been frequently suggested to build subways in the more important streets, and to place all the above-named complicated network of engineering conduits and pipes in the same. While this would, doubtless, tend to secure a more permanent street surface, it involves a very large outlay of money for construction, and the remedy suggested is by no

means free from objections. Some of the most experienced municipal engineers have been opposed to the construction of subways. Much may be said on both sides of the question, but it would lead us too far to discuss the subject in detail. It is doubtless true that the maintenance of a permanent street surface is rendered difficult owing to the continued and repeated breaking up of the pavement for connection of water, sewer, gas and electric conduits.

STREET CLEANING.

We have learned how necessary good street pavements are, not only from the traffic point of view, but more especially from a sanitary standpoint, for the maintenance of the health of a city. But the advantages of well-paved streets count for nothing if the pavements are not thoroughly cleaned at regular and frequent intervals.

Street cleaning in the widest sense of the term includes the sweeping of roadways, sidewalks and gutters, the collection and removal of the road dirt, the sprinkling of streets, the removal of snow, the cleaning and disinfection of public conveniences, the cleaning and flushing of sewer catch-basins, and the removal of house refuse. I shall leave the latter out of present consideration, as it will be referred to further on, when speaking of scavenging, and shall restrict my remarks to a discussion of street dirt. The maintenance of city streets, and the scientific administration of street-cleaning in large cities, require a great deal of engineering knowledge, practical skill and judgment, besides not a little executive ability. It is not often, however, that the matter is considered in this way. Many instances could be quoted where in municipal departments mere politicians are placed in charge of the street-cleaning bureau, no doubt because street cleaning, like the construction of a state capitol, often involves the employment of a large force of laborers whose political vote may thus be controlled at election time. Street cleaning may legitimately be considered one of the important problems of sanitary municipal engineering. Viewed in this light, the recent appointment, by a reform mayor, of an able civil and sanitary engineer of high reputation, to

the position of street-cleaning commissioner in the city of New York, cannot be too highly commended.

The quantity and the composition of street dirt depend upon a great many points, such as the character and material of the pavement, the width of the street, the density and class of population, the nature and size of the traffic, the condition of the weather, etc. Road detritus is composed chiefly of abraded particles of stone, wood, iron and shoe leather; gravel, sand or mud from the subsurface; the horse-dung and urine of animals, mixed together with house refuse, ashes, street and yard sweepings, more or less garbage, dead leaves and other vegetable matters. Some of this dirt, and particularly that of animal origin, becomes absorbed in the joints or cracks of ill-laid or ill-kept pavements, where it keeps the subsoil damp and contaminated, putrefies and causes noxious smells and disease-breeding emanations. A part of the street dirt is breathed directly into our lungs, or enters the alimentary canal, and may cause internal diseases. When the March winds blow, and in dry seasons generally, the dust and dirt of streets is wafted about in the air, becomes injurious to the eyes of pedestrians, and is driven or blown into our houses, where it soon settles on the skin and the clothes of persons, on furniture, draperies, curtains and carpets. To avoid this, windows are kept closed and thus the rooms of our houses do not receive the necessary change of air. The street dust is also highly injurious to tradesmen's and shopkeepers' goods. When wet the dirt is changed into street mud, which is destructive to people's clothing, shoes and to carriages. Muddy and greasy streets also become a source of trouble by being slippery, and causing on sidewalks, street-crossings and in the carriage ways, numerous accidents to life and limb, to men and horses. As a rule, street dirt or mud is particularly bad about public hack stands, on open squares, near hotels, theatres and railway stations. Regarding the comparative quantity of street dirt from different pavements, an English engineer is authority for the statement that one cartload of street mud is, on the average, removed from 344 square yards of macadam, from 500 square

yards of granite, from 1,666 square yards of wood and from 4,000 square yards of asphalt pavement.

It is well known that streets in a bad condition are an obstruction to traffic, and that they necessitate a waste of energy and tractive force. We are accustomed to consider muddy streets as an annoyance, and we condemn unclean streets principally on account of untidiness of appearance. Very few people, however, take into consideration that, owing to air and soil pollution, caused by accumulation of dirt and refuse matter and soakage of liquid impurities, there is a powerful influence on public health, which by far outweighs all other disadvantages. It is a fact that clean and well-kept streets cause a marked reduction in the death rate of large cities, particularly as regards malarial and pulmonary ailments. Children playing in unclean streets are more or less affected, being often much more susceptible than adults; the same is true of invalids, and people not in robust health. Sanitary science, therefore, requires that the street surfaces be impermeable and that all thoroughfares should be kept scrupulously clean. Near children's schools, near institutions, and near hospitals the streets should, for obvious reasons, be swept with particular care, and be arranged with a view to perfect drainage. In all advanced schemes for the ventilation of buildings the fact that street dirt is injurious to health is taken into consideration, by providing special means for screening and filtering the air supply from outdoors, or by washing out its impurities. Dirty and dusty streets exercise at all times indirectly a baneful influence upon the salubrity of habitations, because they prevent the free ventilation of living or sleeping apartments by the opening of windows.

We have yet much to learn from Continental cities, which are far ahead of ours in the matter of street cleaning. This fact is generally conceded by all Americans who have travelled with open eyes through Europe, and who have admired the tidy and well-kept streets of some of its capitals. It is a matter beyond comprehension to me how the mayor of a large American city, after returning from a trip to England and the Continent, could have stated, as the news-

papers reported, that, in the matter of street cleaning, American cities had nothing to learn from cities like Paris, London, Berlin or Vienna.

The work of street cleaning presents difficulties which are not easily surmounted, chiefly on account of the enormous quantities of street refuse to be removed daily. It is accomplished by scraping, sweeping, washing and flushing. The sweeping may be done by hand labor with brooms, or else by the use of special machinery. Owing to the greater rapidity with which work is done there is economy in using the best machinery, implements and tools available. Mechanical sweepers should displace hand labor, for street cleaning by hand is from three to six times as expensive as cleaning by the aid of machines. It is a curious fact that the first street-cleaning machine, devised by Sir Joseph Whitworth, was rejected "as interfering with the labor for poor people." Street sweeping should always be done without stirring up dust and dirt. Hence, water is needed in street-cleaning operations, and all streets should be sprinkled before sweeping.

Carelessness in street sweeping should not be tolerated. In all large cities, street cleaning should be preferably done at nighttime. The method of cleaning streets by washing the filth and dirt into the gutters and catch-basins, and thence into the street-sewers, cannot be approved, except in special instances, as it simply transfers the dirt from the street surface to the catch-basin and the sewer. Dry removal of street dirt in large, well-built, covered carts is much to be preferred. Horse-droppings on important thoroughfares should always be picked up at once and removed with brushes into handbags. The fact should be noted that the extensive application of steam and electricity to replace horse traction in surface roads tends to reduce the amount of organic street dirt. The ultimate disposal of the collected street refuse is another problem which may present difficulties in large cities with many miles of pavements.

REMOVAL OF ICE AND SNOW.

A problem which, in winter time, taxes the ingenuity of the engineer of a street-cleaning department to the utmost,

is the removal of a sudden fall of snow, particularly when the snow storm is accompanied by high winds, causing the snow to collect in drifts. The snow, accumulating on sidewalks and footpaths, must be swept off by the adjacent householders, and fines should be enforced for non-compliance with the city ordinances. The snow is best removed as soon as the storm subsides, for when hard-trodden the mass is more difficult to handle. Sidewalks in front of vacant lots or unoccupied houses should be, under all circumstances, included in the city regulations, and if their owners are negligent, the cleaning should be done by the city, and the cost assessed upon the property.

The removal of snow from the carriage way is difficult to accomplish when the fall is heavy. Few persons realize the enormous quantities to be removed. Street railroad companies, after using the snow-plough to clear their tracks, should, by city ordinance, be required to remove that portion which they pile up outside of the tracks.

The mode of disposing of the snow varies according to the location of a city. In districts which adjoin a river or canal, or a harbor, the snow may be dumped from the carts into the water. In some cases it is thrown into the sewer man-holes. Owing to the fact that snow from frequented thoroughfares is generally mixed with street mud and road scrapings, the former method is often objectionable, as it causes the harbor or water-course to silt up, and necessitates dredging, and the second method should only be adopted if the sewers are simultaneously flushed with large quantities of water, otherwise it leads to deposits of mud in the sewer inverts. Melting the snow by fires, or by steam jets has been tried, but it is a slow and expensive proceeding. The use of salt to hasten the melting of snow is quite objectionable, as it causes a deep slush, and should only be tolerated when the slush is at once swept into the street gutters. Salting sidewalks or car tracks is very objectionable, from a health point of view, as the mixture causes much cold dampness, ruins pedestrian's clothing and shoes, is injurious to horses' hoofs, and causes the feet to be severely chilled, inducing colds, pneumonia, or the grippe.

STREET SPRINKLING.

In summer time, and in dry weather generally, city streets should be sprinkled to cool the air in hot weather and to keep down the street dust, with its many annoyances and inconveniences. Street sprinkling is accomplished largely by means of watering-carts or vans, but sometimes hose jets are used, or the street is watered by means of perforated pipes on wheels, attached directly to the street hydrants. The latter method is particularly adapted to well-kept impermeable asphalt pavements. The beneficial effect of street sprinkling upon the air is very marked; the air is washed of impurities, it becomes refreshed, and a feeling of relief is experienced similar to that after a thunder shower. It is a mooted point whether street sprinkling should be done by the city from the general improvement fund, or by private firms or corporations paid by the property owners of streets. I cannot see why street sprinkling should not be looked upon as a part of the general street cleaning system. The general traffic and pedestrians are certainly benefited by it quite as much as the owners of the property bordering on the street. It has been suggested in seaboard towns to water the streets with sea water, and the matter seems well worth trying, as it reduces the demand made upon the general city water supply in periods of drought, and also because salt water keeps the street surface damp for a greater length of time.

CLEANSING FOOTWAYS AND SIDEWALKS—STREET CROSSINGS—GUTTERS.

The sidewalks of streets should be kept scrupulously neat and clean. All accumulation of mud should be avoided, because it tends to make the sidewalks slippery. In winter snow should be regularly removed, and when ice forms it should be covered by the householders with sand or ashes, to prevent accidents and to avoid damage suits.

All street crossings need the particular attention of the street cleaners. They should be cleaned, swept and the mud raked off, and during snowfalls they ought to receive

attention first, so as to re-establish the regular street traffic with as little delay as possible.

The maintenance of the street gutters is particularly important from a sanitary point of view. Filthy gutters in hot weather are a source of danger, and cause noxious odors. They should be daily swept and kept unobstructed, to secure a rapid drainage of the street surface; there should be no pools of stagnant, offensive liquids in the gutters; they should be kept impervious to avoid leakage into the subsoil or into cellars, and they should have a continuous grade to the nearest sewer inlet. After snowfalls, gutters and inlets of catch-basins must be kept clear, so that when a thaw occurs there will be no flooding, rendering street crossings impassable.

REMOVAL OF REFUSE—GARBAGE DISPOSAL—SCAVENGING.

While sewers are intended to remove from habitations all liquid and semi-liquid organic matters, the solid refuse of a city, of its houses and streets, comprising ashes, offal, garbage, house-sweepings and street refuse must be removed by cartage. Sir Robert Rawlinson, one of the foremost sanitary engineers of England, calls scavenging one of the important features of city sanitary engineering. In dealing with this problem distinction is often made between regular and special refuse. It would be tedious to you, doubtless, if I were to enter into the subject fully, enumerating at length what constitutes ordinary house refuse. I shall, therefore, merely state that all house refuse should be divided into two distinct kinds, viz.: garbage and ashes, the former largely organic, the latter inorganic masses.

Scavenging deals not only with house refuse, but also with street refuse, with stable, garden and trade refuse, with market refuse, builders' rubbish and with the mud accumulating in street catch-basins. House refuse, paper and litter, should never be deposited in the roadway, nor should any of it be thrown into sewer man-holes or catch-basins. Pending removal, house garbage and rubbish should be stored in dust-bins or in barrels and ash cans, and it is essential, and by no means difficult to enforce,

that separate vessels be provided by householders for the garbage or swill, and the ashes and sweepings. Large fixed receptacles for temporary retention are not as desirable as small portable pails or cans, except, possibly, for large tenement houses.

The garbage pails should be of non-absorbent material, and ash cans should not be of wood, but of iron, to avoid danger of fire from hot ashes. All receptacles should be provided with tight-fitting covers, so that when they are placed on the sidewalk near the curb just before the scavenging cart arrives, the ashes may not be scattered by the wind, and the swill and offal may not offend the senses of passers-by when exposed to the rays of a hot July sun. I cannot discuss the details of the removal, except to say that it should be done at regular hours at all times, and that garbage must be more frequently removed in summer than in winter, to avoid the emanations due to rapid decay.

The city should, of course, provide separate garbage and ash carts of solid construction and fitted with covers to avoid a street nuisance during transportation. In summer time householders may help to reduce the amount of offal to be disposed of by drying, carbonising and burning some of the house garbage in the kitchen range.

Regarding the ultimate disposal of city refuse, it is found by experience that much of it may be utilized, after sifting and separating the coarser from the finer materials. This sorting of the contents of ash and garbage barrels should never be permitted to be done in the streets. The city refuse dumps are the places to which ragpickers should be relegated. All dirt, as Lord Palmerston said, is merely "matter in the wrong place." While ashes, cinders and clinkers may be utilized for the filling up of sunken lots or for making river banks or roads and pathways, no garbage should be so used or mixed in any way with ashes. Horse droppings from streets are salable as manure, and some part of the house offal can be disposed of to farmers for like uses. But whatever cannot be utilized in some way, must be removed by rail or by water. In harbor towns, city refuse is taken in specially constructed hopper barges far out to sea,

and dumped into deep water. This mode of disposal is not always desirable or feasible, as it may lead to a defilement of the beaches and bathing resorts near the city. There is little doubt that destruction of garbage by the all-purifying element—fire—is one of the best, if not *the* best, method from a sanitary point of view. Various refuse cremators have been contrived, which are operated successfully without causing a nuisance by the smoke and gases from the furnace. The ashes resulting from cremation have some value as fertilizers, particularly where sewage sludge or nightsoil is mixed with the refuse.

The cleaning of earth closets, privies, ashpits, cesspools, vaults, and sewer catch-basins is also a part of the city scavenging, but it would lead me too far to discuss the same.

[*To be concluded.*]

REASONS FOR PREDICTING THE EXISTENCE OF ARGON.*

By C. J. Reed.

Berzelius, about a half a century ago, advanced the theory that a compound molecule is made up of atoms having opposite electrical polarities. This theory, in the form proposed by Berzelius, would not explain the substitution of an electro-negative for an electro-positive atom in a molecule, and the theory soon fell into disrepute.

About fifteen years ago Prof. Otis C. Johnson revived this theory in a modified and greatly improved form.

Professor Johnson first assumed that the algebraic sum of the affinities in a molecule is always zero. He then, by definition, makes oxygen an arbitrary standard of valence and polarity, by assuming that in combination it is always an electro-negative dyad. It follows that the valence and polarity of other elements with respect to oxygen is variable, and is determined in any particular compound by the rule

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* Read at the meeting of the Chemical Section, May 21, 1895.

that the sum of the affinities in a molecule is zero. This theory, properly understsod, is not inconsistent with the substitution of electro-positive for electro-negative atoms in a compound molecule.

On this theory he found that oxidation is always equivalent to a change of affinity or bonds in one direction, and reduction to a change in the opposite direction, and that these two changes are always equal.

About ten years ago it was shown by the writer, in a paper read before the St. Louis Academy of Science, that a remarkable relation exists between the electro-chemical affinity and the atomic weight of an element. It was shown that the saturation valence is an equi-crescent rotary, or helical, function of atomic weight.

By the method of rectangular co-ordinates, points were located in a plane for each of the elements. Ordinates were taken proportional to the saturation valence—that is, to the maximum or minimum valence, or in some cases to the characteristic valence. Abscissas were taken proportional to the atomic weight. Electro-positive valence was measured upward, and electro-negative valence downward, from the axis of abscissas. *Fig. 1*, reproduced from the paper referred to above, shows this arrangement of the elements. The only changes that have been made from the original figure are the addition of a few elements since discovered, some slight changes in the atomic weights of a few elements, and the addition of the hypothetical element *A′*.

An inspection of this figure shows that nearly all of the elements fall on a peculiar series of double, equi-distant parallel lines, separated alternately by distances of one and sixteen units of atomic weight. This is particularly true of the elements of low atomic weight, scandium being the first notable exception. Beginning again at *Ge*, we find a remarkable tendency of the elements to follow the lines from *Ge* to *Mo*. From *Ru* to *Te* there is a diagonal movement from one pair of parallels to the next. From *Te* to *Ce* the arrangement is more regular. Between *Os* and *Bi* this regularity is again plainly recognizable.

Those elements which follow the general course of the

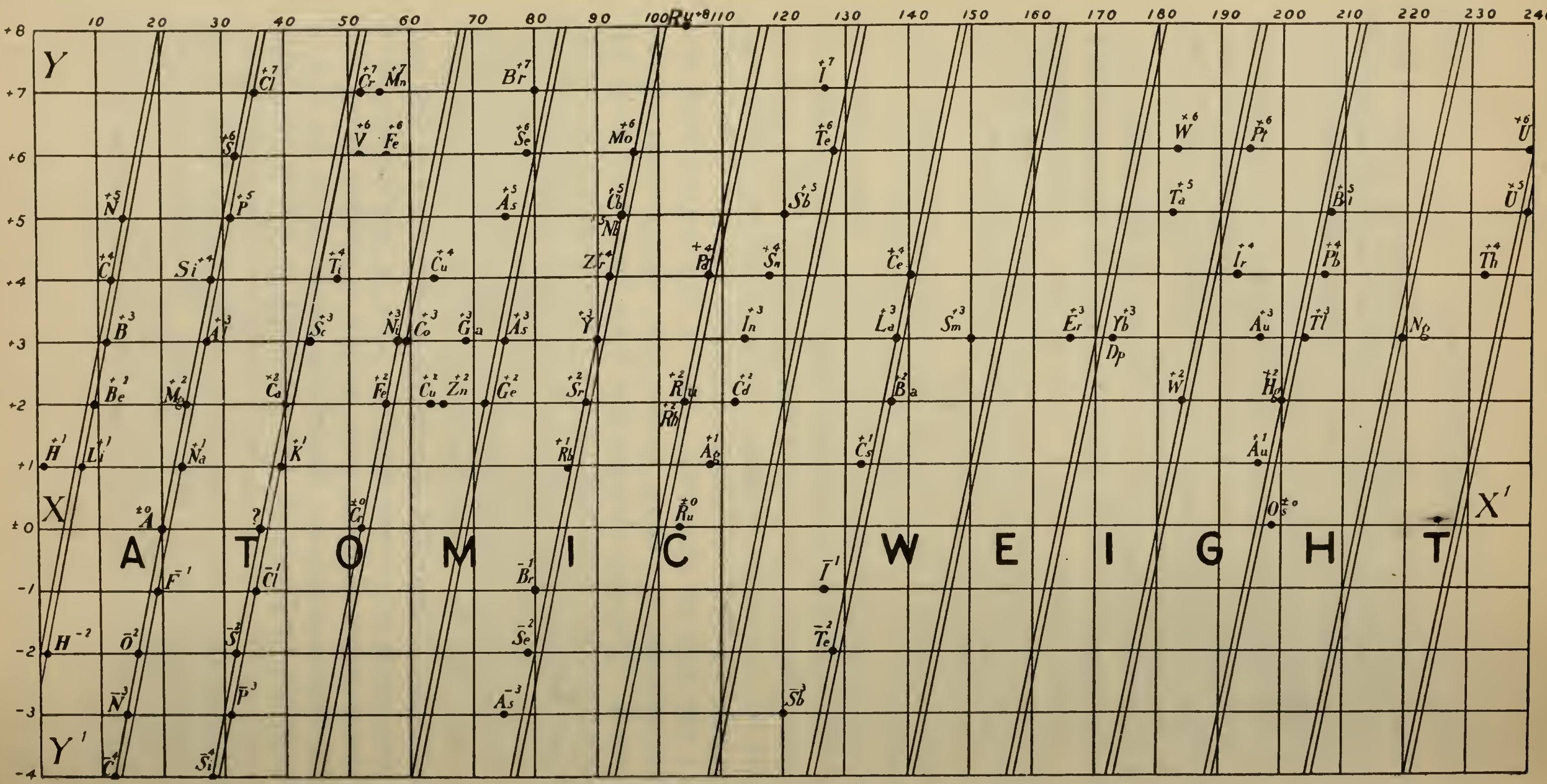


FIG. 1.—DIAGRAM SHOWING THE RELATION BETWEEN VALENCE AND ATOMIC WEIGHT.

parallels, without actually falling on the lines, generally deviate either towards the left or towards the vacant region.

Perhaps the most remarkable thing shown on this diagram is the manner in which the successive pairs of parallels are linked together and their distances pre-determined by the connection between maximum and minimum valence.

It is a very remarkable fact that all the so-called non-metallic elements, that is, elements that exhibit both electro-positive and electro-negative affinities, have a well-defined positive maximum and a well-defined negative minimum valence, which differ by eight units, thus:

C is + 4 in CO_2 and carbonates,	
C is — 4 in H_4C,	difference 8.
N is + 5 in HNO_3 and nitrates,	
N is — 3 in H_3N,	difference 8.
Si is + 4 in SiO and silicates,	
Si is — 4 in H_4Si,	difference 8.
P is + 5 in HPO_3 and phosphates,	
P is — 3 in H_3P and phosphonium salts,	difference 8.
S is + 6 in SO_3 and sulphates,	
S is — 2 in H_2S and sulphides,	difference 8.
Cl is + 7 in $KClO_4$ and perchlorates,	
Cl is — 1 in HCl and chlorides,	difference 8.
As is + 5 in As_2O_5 and arsenates,	
As is — 3 in H_3As,	difference 8.
Se is + 6 in SeO_4 and selenates,	
Se is — 2 in H_2Se and selenides,	difference 8.
Br is + 7 in $HBrO_4$,	
Br is — 1 in HBr and bromides,	difference 8.
Sb is + 5 in Sb_2O_5 and antimonates,	
Sb is — 3 in H_3Sb,	difference 8.
Te is + 6 in TeO_3 and tellurates,	
Te is — 2 in H_2Te and tellurides,	difference 8.
I is + 7 in H_5IO_6 and periodates,	
I is — 1 in HI and iodides,	difference 8.

This includes all known elements, except hydrogen, which exhibit well-marked positive and negative affinities.

It will be seen, by inspection of *Fig. 1*, that if a vertical displacement of eight units of valence is made in the third

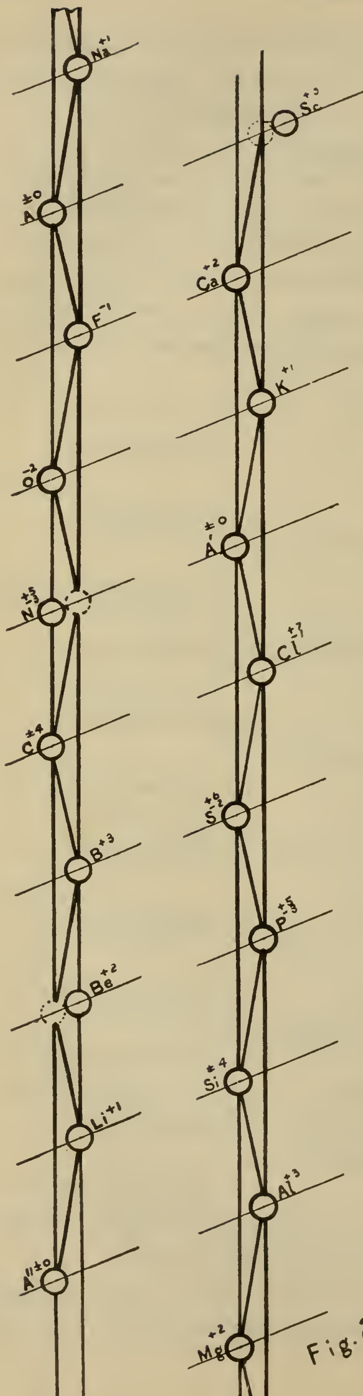


Fig. 2

pair of lines it will bring the maximum and minimum values of Si, P, S and Cl into coincidence, and that the third pair of lines will then be a continuation of the second. The same effect is produced on all the lines, without any vertical displacement, by bending the plane into a cylinder having a circumference equal to eight units of valence. The parallels are thus all united into a double helix, the axis of abscissas forming an element of the surface of the cylinder. The axis of ordinates becomes a circle of the cylinder, and valence, now measured in angular measure, is directly proportional to atomic weight. The double helix becomes a sort of chain, on which the elements are arranged as shown in *Fig. 2*.

In this figure we find other striking analogies. With the exception of *Be* and *N*, the artiads are all on one line and the perissads all on the other. The alternate arrangement is extremely regular. Before the discovey of argon by Lord Rayleigh and Professor Ramsay, there was a vacancy at *A*, *Figs. 1* and *2*, requiring an element of atomic weight, 20; another at *A'*, requiring an element of atomic

weight, 36, and another at A'', requiring an element of atomic weight, 4. To conform with the analogies of the rest of the chain, these elements should have an affinity or valence of — 0 or + 8; that is, should be either incapable of combining with other elements, or else should have a maximum or characteristic valence of eight. In order to judge further of the properties of these unknown elements, we refer again to *Fig. 1*. We observe that the surface of the cylinder is divided longitudinally into eight equal parts, by the parallels of equal valence, the axis of atomic weights representing the valence + 0 and + 8; that the double helix, which we may call, for convenience, the locus of elements, cuts the axis of atomic weights at fifteen points, suggesting that there should be a group of fifteen elements having a valence of zero or eight, and that their atomic weights should be, respectively, 4, 20, 36, 52, 68, 84, 100, 116, 132, 148, 164, 180, 196, 212 and 228. But as all the known elements appear to be grouped together in certain regions of the cylinder, while the remaining portions are comparatively bare, we should naturally expect this to be true also of the new family of elements. The only members of this family, therefore, which we can reasonably expect to find in terrestrial matter are those occurring in the same regions. The only members of this group occurring in such regions are 1, 2, 3, 4, 6, 9 and 13, having atomic weights, respectively, 4, 20, 36, 52, 84, 132, 196; and possibly No. 7, having atomic weight, 100.

The most necessary of these are numbers 2, 3, 6 and 9, having atomic weights respectively, 20, 36, 84 and 132.

As to the properties of this new group of elements, little can be said, except in a very general way, owing to their peculiar position on the border line between the extremes of electro-positive and electro-negative affinity.

The following deductions, however, seem reasonable from the position of these elements with reference to that of known elements, as shown in *Fig. 2*.

The members of this group, when in the electro-negative state, should be more strongly electro-negative than the corresponding members of the sulphur group, and yet they should be without combining affinity.

The argon group are artiads, as they occupy a regular position on the artiad helix. Their characteristic valence is 0 or 8—that is, they should combine as octads, or else be incapable, or nearly incapable, of combining with other elements.

The possible number of these elements having atomic weights below 240 is fifteen, since the elemental locus cuts the axis of abscissas at that number of points. But only four, or at most six, of these are likely to be found in nature. Those most likely to be found are, in the order of their probability, argon, having an atomic weight, 20, which has lately been discovered by Lord Rayleigh and Professor Ramsay; *A′*, having atomic weight, 36; one having atomic weight, 84; and one having atomic weight, 132.

Like all electro-negative elements (except *C* and *Si* in the free state), they and their oxides and hydrides should be volatile.

As oxygen is more volatile than carbon, sulphur more volatile than silicon, fluorine (probably) more volatile than nitrogen, chlorine more volatile than phosphorus, bromine more volatile than arsenic, and iodine more volatile than antimony, we should expect from analogy that argon would be more volatile than oxygen; the element 36 more volatile than sulphur; the element 84 more volatile than selenium; and the element 132 more volatile than tellurium. In general, any member of the new group should be more volatile than the corresponding member of the sulphur group.

Argon and element 36 should, like most elements of low atomic weight, be comparatively abundant in nature, while elements 84 and 132 should be scarce, but not more rare than selenium and tellurium.

As the intensity of electro-negative affinity in any group diminishes with increase of atomic weight, and as electro-negative valence is not known in elements of higher atomic weight than 130, the element 196, if it exists, could not be expected to exhibit negative valence. This element should be a volatile metal, heavier and scarcer than gold and capa-

ble of easier reduction to the metallic state; also, it should be capable of forming an oxide of the formula RO_4, or a salt of the formula K_2RO_5. The volatile metal, osmium, agrees with the requirements of this element very closely, while ruthenium may possibly be the element 100.

Elements of this group will not combine easily with one another, and those of low atomic weight will probably not combine with any element, except possibly to form one or two unstable compounds which can exist only at low temperatures.

The lower members of this group should be decidedly non-metallic, like the lower members of all electro-negative groups.

The necessity for these elements impressed me very

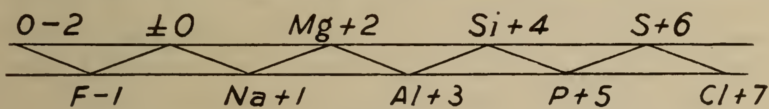


FIG. 3.

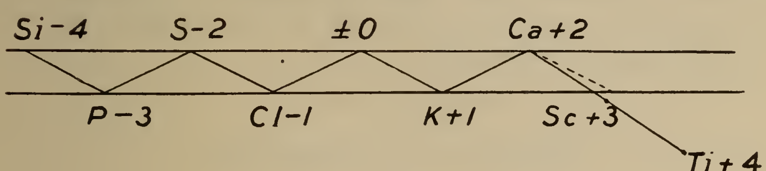


FIG. 4.

strongly at the time the paper above referred to was written, and in *Figs. 3* and *4* of that paper, reproduced here in facsimile, I actually marked the position of argon as an element having atomic weight, 20, and that of another element having atomic weight, 36, both being marked by the symbol $\pm$ 0.

In closing, it will probably be of interest to note that since the publication of the discovery of argon, M. DeBoisbaudran has stated (see *Chem. News*, **71**, 116) that he has found a classification of the elements that enables him to assume the existence of a family of elements, no member of which was known; that their atomic weights are, respectively, 20·0945, 36·40 $\pm$ 0·08, 84·01 $\pm$ 0·20, and 132·71 $\pm$ 0·15, assuming $O = 16$. He states that they should be non-

metallic, that the bodies, 20·0945 and 36·40 should be relatively abundant in nature, the other two rare.

"The atomicity of the new family should be even (octovalent), but its component elements should be devoid of the faculty of combining with other elements.

"The element 36·40 should be more volatile than sulphur and the element 20·0945 more volatile than oxygen. Lastly, the elements 84·01 and 132·71 should be, respectively, more volatile than selenium and tellurium."

As M. DeBoisbaudran neither gives the reasons for his deductions nor explains his classification, I am unable to state whether there is any similarity between his system and my own. His conclusions, it will be noticed, are remarkably similar to mine, the principal difference being that M. DeBoisbaudron carries his predictions on atomic weights in some cases to the fourth decimal place; while there is nothing in my classification to warrant a more accurate prediction than the nearest whole unit. I am inclined to believe from the position of the elements, As, Se, Br, Sb, Te, I, and Cs, that the atomic weights 84 and 132 may be a unit too high.

NOTES AND COMMENTS.*

AMERICAN TOOLS IN ENGLAND.

The Iron Age, in a recent impression, prints an interesting interview with the representative of a leading English firm of engineers and importers of American machinery, which has been engaged in the business for thirty years.

The following quotations from this source will doubtless be read with interest, viz.:

It appears to be, first and broadly, that high-grade tools, both special and standard, are in demand. Tools of poor design and showing poor workmanship are not wanted, and the attempt to introduce them has not proved successful. Users of machine tools in England have become convinced of the superiority of American makes of tools of certain descriptions. This refers particularly to the automatic and universal machines, such as automatic screw and bolt machines and universal grinders. These two are merely mentioned as an indication of the type of machines which find ready sale. The

* From the Secretary's monthly reports.

THE MINERAL PRODUCTION OF THE UNITED STATES—1893-1894.

The accompanying table, exhibiting the amounts and values of the various mineral products of the United States for the years 1893-1894, we are permitted to print by courtesy of Mr. R. P. Rothwell, editor, from advance sheets of "The Mineral Industry," vol. iii.

MINERAL PRODUCTION OF THE UNITED STATES, 1893 *and* 1894.

Compiled for THE MINERAL INDUSTRY, Vol. III.,
By Richard P. Rothwell, editor of "The Engineering and Mining Journal."

No.	Products.	Customary Measures.	1893. Quantity. Customary Measures.	1893. Quantity. Metric Tons.	1893. Value at Place of Production.	1894. Quantity. Customary Measures.	1894. Quantity. Metric Tons.	1894. Value at Place of Production.
	NON-METALLIC.							
	Abrasives—							
1	Corundum and emery...	Short tons....	1.747	1,585	$140,589	1,220	1,106	$109,500
2	Garnet..............	"	1,520	1,379	55,800	1,000	907	35,000
3	Grindstones	"	45,340	41,133	345,920	37,400	33,922	335,800
4	Millstoues	"	155	141	2,359	297	269	4,447
5	Tripoli and infus. earth..	"	1,351	1,226	25,625	1,802	1,634	36,687
6	Whetstones.............	" ...	1,903	1,726	89,550	1,735	1,574	84,450
7	Alum	"	96,000	87,093	2,880,000	72,000	65,304	2,160,000
8	Antimony ore..............	"	850	771	41,000	165	150	9,075
	Asbestos and Talc—							
9	Asbestos..................	"	120	109	6,000	250	227	3,750
10	Fibrous talc.............	"	36,500	33,113	337,625	39,600	35.917	396,000
11	Talc and soapstone......	"	20,100	18,235	366,825	21,044	19,087	401,892
12	Asphalt....................	"	3,490	3,166	68,682	4,198	4,080	75,654
13	Bituminous rock..........	"	31,404	28,489	114,752	34,199	31.018	148,120
14	Barytes....................	"	26,632	24,161	133,160	23,758	21,548	95,032
15	Bauxite....................	Long tons....	11,041	11,222	55,205	10,732	10,908	42,928
16	Borax	Pounds.......	9,199,000	4,173	689,925	13,140,589	5,962	919,841
17	Bromine...................	"	348,399	158	87,100	379,444	172	98,655
18	Cement, natural hydraulic	Bbls., 300 lbs..	7,445,950	1,013,238	5,010,958	7,895,259	1,074,179	4,397.407
19	Ceuent, Portland.........	" ..	673,989	91,715	1,052,173	738,196	100,352	1,080,644
20	Clay, refractory..........	Short tons....	3,214,989	2,916,591	4,822,483	3,375,738	3,061,794	4,050.885
21	Clay, kaolin................	"	30,183	27,382	205.667	24,552	22,246	185,169
22	Coal, anthracite...........	"	*a*47,355,387	42,960,116	74,605,885	*a*52,010.433	47,183,345	80,879,404
23	Coal, bituminous	"	*a*128,826,364	116,869.397	123,899,415	*a*117,950,348	106,953,311	103,842.467
24	Coke.......................	"	8,939,961	8,110,245	14,706,544	8,495,295	7,706,846	12,654.558
25	Cobalt oxide...............	Pounds.......	3,894	2	5,452	6,550	3	8,843
26	Copperas	Short tons....	17,862	16,204	134,520	14,897	13,511	104.160
27	Copper sulphate...........	Pounds.......	54,000,000	24,492	1,822,500	*e*60,000,000	27,215	2,016,000
28	Chrome ore................	Long tons....	4,629	1,646	16,000	2,653	2,697	35,125
29	Feldspar..................	"	17.000	17,274	85,000	23,280	23,655	116,400
30	Fluorspar..................	Short tons....	9,700	8,800	63,070	9,000	8,165	64,000
31	Graphite..................	Pounds.......	882,912	400	39,731	770,846	349	34,689
32	Graphite, amorphous......	Short tons....	1,691	1,534	8,996	165	150	1,252
33	Gypsum....................	"	330,231	299,582	927,615	287,517	260,834	849,925
34	Lime.......................	Bbls., 200 lbs..	*e*60,000.000	5,443,164	30,000,000	*e*56,750,000	5,148,326	28,375,000
35	Magnesite	Short tons....	1,143	1,037	8.000	1,370	1,243	4.864
36	Manganese ore	Long tons....	9,150	9,297	60,000	11,735	11,924	74,890
37	Mica, ground.............	Pounds.......	679,000	308	29,522	829,500	377	35,957
38	Mica, sheet...............	"	6,500	3	5,478	9.900	4	11,103
39	Monazite..................	"	130,000	59	7.600	750,000	340	45.000
40	Natural gas...............	....	....	....	14,000,000	....	....	11,000,000
41	Paints, mineral...........	Short tons....	44,709	40,559	726,160	38,801	35,200	662,262
42	Paints, vermilion..........	"	37	34	40,000	41	37	45,600
43	Paints, white lead.........	"	88,500	80,286	9,469,500	87,242	78,155	8,445,174
44	Paints, zinc oxide.	"	25,000	22,679	1,875,000	22,814	20,697	1,711,275
45	Petroleum (crude).........	Bbls., 42 gals.	50,349,228	7,043,857	32,223,505	48,527,336	6,788,974	40,762,962
46	Phosphate rock...........	Long tons....	981,340	997,140	3,434,690	952,155	967,485	2,856,465
47	Marls......................	"	200,000	203,814	540,000	225,000	228,622	607,500
48	Precious stones............	....	....	....	200,000	....	....	250,000
49	Pyrites	Long tons....	95,000	96,529	285,000	107,462	109,192	466,466
50	Salt, evaporated.....	Bbls., 280 lbs..	9,703,419	1,232,392	4,945,583	9,161,053	1,163,508	4,608,275
51	Salt, rock..................	" ..	1,935,642	245,838	678.064	2,341,922	297,438	788,681
52	Silica, sand and quartz....	Long tons....	300,000	304,814	330,824	315,531	320,610	347,951
53	Slate, roofing	Squares	803,887	237,014	2,956,895	693,944	204,656	2,551,259
54	Slate, other manufactures.	Square feet...	4,138,920	....	475,681	5,099,791	....	499,578
55	Soda, natural.............	Short tons....	2,500	2,268	12,500	....	....	....
56	Soda, natural sulphate....	"	90	82	450	....	....	....
57	Stone, limestone (flux).....	Long tons....	3,750,000	3,810,375	2,250,000	3,544,398	3,601,458	2,126,636
58	Stone, marble..............	Cubic feet....	5,639,681	429,399	2,087,758	5,681,766	433,093	2,177,280
59	Stone, onyx...............	"	2,175	166	28,750	1,450	110	29,000
60	Other building stones.....	....	....	....	*e*38,000,000	....	....	*e*30,000,000
	Total non-metals..	....	....	....	377,517,086	....	....	353,760,877
	METALS.							
61	Aluminum.................	Pounds.......	312,000	142	202,800	817,600	371	490,560
62	Antimony	Short tons....	350	318	63,000	220	205	39,200
63	Copper	Pounds.......	327,255,788	148,441	35,179,997	353,504,314	160,392	33,540,489
64	Gold.......................	Troy ounces..	1,739,323	*54,093	35,955,000	1,923,619	*59,824	39,761,205
65	Iron, pig...................	Long tons....	7,043,384	7,156,782	93,888,309	6,657,388	6,764,572	71,966,364
66	Lead, value at New York..	Short tons....	166,678	152,080	12,434,178	160,867	145,906	10,585,048
67	Nickel, fine................	Pounds.......	25,893	*11,745	12,429	....	....	....
68	Quicksilver................	Flasks, 76½ lbs	30,164	1,046	1,108,527	30,440	1,056	1,095,840
69	Silver, commercial value...	Troy ounces..	60,500,000	*1,881,731	47,311,000	49,846,875	*1,550,387	31,403,531
70	Zinc spelter................	Short tons....	76,255	69,178	6,214,782	74,004	67,135	5,209,882
	Total metals............	....	....	....	232.370,022	....	....	194,092.119
	Est. products unspecified..	....	....	....	6,000,000	....	....	5,500,000
	Grand total............	....	....	....	615,847,108	....	....	553,352,996

(*a*) Bituminous coal includes brown coal and lignite. The anthracite production is the total for Pennsylvania, Arkansas and Colorado. (*e*) Estimated. * Kilograms.

heavier types of tools, such as mammoth lathes, planers, boring mills and the like, have not as yet found much of a footing abroad. A large sale is carried on in the finer measuring instruments, such as micrometers and vernier calipers, and also in cutting and milling machines. There is also a demand for American hand saws, hack saws, power hack saw machines, vises, lathe chucks, drills and the like.

Those machines of American make which appear to have, in a certain sense, become standard abroad are drill presses, emery grinders, milling machines of the comparatively smaller sizes, and lathes. According to the statement of Mr. ———, those tools which are of a superior design, are perfectly adapted to the work, and which show extreme accuracy in their construction and finish, are the easiest to sell. While attempts have been made in England, and especially in Germany, to copy these tools of the highest grade, the attempt has been unsuccessful, because not enough attention was paid to the accuracy of fit.

Concerning the question as to whether there is any prejudice among managers and workmen in England against American-made tools, Mr. ——— said that at the present time certain makes of American tools are well known over there and are received with pleasure in the shop. Formerly this was not the case, and their introduction was sure to result in ruin, or the attempt to ruin, the machine by the workman placed in charge. But after the workman has become accustomed to the American machine he objects strongly to being placed again in charge of his old machine. The reason is he has found out the superior advantage of the new machine, and for that reason does not care to go back to his old one.

Automatic machines, such as screw machines, several of which are commonly placed in charge of one workman in this country, are run singly in England. This is due to the influence of the trades unions in England. These associations control the men to such an extent that they dictate how many machines the man shall run, and except in special cases they refuse to let him take charge of more than a single appliance. This, in a case of four small milling machines, was got around by the superintendent, who mounted four machines upon one base, this being considered as practically forming one machine, although the capacity of that machine was quadrupled. Nevertheless, it satisfied the demands of the trades unions and prevented trouble.

Building on the "interchangeability of parts" system, so largely in vogue here, has assisted greatly in the introduction of tools abroad. It has been found that duplicate parts could be obtained from the builders cheaper than they could be produced at the English shops. Further than this, and more important, parts so obtained are sure to fit accurately, while those made to order might not.

THE TROLLEY CARS AS LIFE SAVERS.

Everything depends on the point of view from which a subject is examined, as the following communication from a citizen of Brooklyn (where the

victims of the trolley cars, at this writing, considerably exceed 100 in number), lately published in one of the local newspapers, will demonstrate:

"For some reason the newspapers have had a good deal to say in condemnation of the trolley car and its record of 'one hundred fatal accidents' in Brooklyn. It seems to me that the case is not sized up judicially, and that most of the blame is misplaced. Nearly every fatality of this class has resulted from contributory negligence or gross carelessness, or even from suicidal purpose. The trolley has no monopoly as a source of danger. Children who are allowed to run the streets without being properly cautioned, and grown people who, from intoxication or any other cause, tempt fate recklessly, are always liable to disaster, fatal or otherwise. A larger number of people have been drowned by falling into the water from the piers, since the advent of the electric motor, than the trolley has to its credit, yet the papers have failed to harp on the deadly dock.

"The trolley, by lessening the defilement of the streets, has so ameliorated the sanitary condition of the city atmosphere that it has saved many times the number of lives it has destroyed. It has furnished a quick and comfortable transit to the outlying wards, which has reduced the prevalence of grippe and pneumonia among the suburban passengers more than one-half. Many can recall the winter cars with their slush-soaked straw and foul odors, and the tiresome and dangerous delays in the snow, when the passengers were forced to walk in the storm, or even to assist the wretched horses by pushing. Many a man has gone down to his grave from a cold contracted on such a trip. The trolley has saved thousands of lives by enabling the mechanic and clerk to move their little ones from the unwholesome tenements of the city to the pure air and sunshine of the country. It has added, in dozens of ways, to the sum of human welfare. Why, then, does the press persistently attack a system which accomplishes so much good that it has become a great public necessity?"

ARTIFICIAL SILK.

Consul Germain, of Zurich, Switzerland, speaks quite favorably in recent reports to the Department of State (see Consular Reports, Nos. 171 and 173) of the commercial possibilities of the artificial silk made by the process and apparatus devised by Dr. Lehner, of that city. A plant for the manufacture of the product has been erected at Glattbrugg, near Zurich, where the raw material is forwarded to England for manufacture into fabrics.

The accompanying extract from the English Company's prospectus appears in the last-named report of the Consul, viz:

"Lehner's artificial silk is a new material for use in textile manufacture, possessing distinct and valuable characteristics, which render it unique among all fibres hitherto existing. As the result of study and analysis of the natural methods of production of silk by the silkworm, the inventor has, by simple chemical and mechanical means, closely and successfully reproduced a natural process. Wood pulp, cotton or jute waste, etc., are chemically digested and the liquid product is spun by a mechanical silkworm to a thread of even diameter throughout and of unbroken and unlimited length. The

same machine which draws the threads from the liquid twists these threads in any desired number into the requisite 'count,' or thickness of yarn, in one uninterrupted and continuous process, with perfect regularity. The machine is inexpensive and extremely simple. It can be run day and night without intermission, and requires but little power and attention.

"The principal features of this process are: (1) Never-failing supply of the raw material; (2) practically uniform price of same; (3) simplicity of machinery, so as to avoid risk of breakdown; and (4) no skilled, and only a small amount of low-priced, labor is necessary.

"The production of Lehner's artificial silk is entirely independent of climate, temperature, special soil or cultivation.

"Lehner's artificial silk has been spun in Bradford, and has been worked up in a large variety of fabrics. In the dyeing, weaving and finishing of these sample fabrics, no special treatment has been necessary. Unlike most vegetable fibres, Lehner's artificial silk can be dyed in all colors, and the shades obtained excel in brilliancy and delicacy those of the finest natural silk.

"For softness and beauty of appearance the new material equals the best Chinese and Italian silks. By its use, therefore, in combination with cotton, wool or natural silk, brocaded and other ornamental and decorative results can be obtained, which have hitherto been unattainable, except by the employment of the finest trams and the expensive character of these necessarily limits their sale for this purpose. The cost of Lehner's artificial silk being small, it follows that that fibre will open out a large and profitable new field to manufacturers, affording encouragement to them in the production of an unlimited variety of both choice and salable novelties in fabrics of almost every description."

While the operative methods of producing this product apparently differ from those employed in the preparation of the "artificial silk" of Chardonnat, the pioneer inventor in this field, the product itself is doubtless identical, both consisting of a thread of cellulose made by appropriate chemical treatment of filaments of nitrocellulose. The serious objection to this "artificial silk," and which will probably prevent it from being used alone, that is, without admixture with natural fibres, is its deficiency in strength. This defect may, however, not interfere with the use of the product in making mixed fabrics.

POSSIBILITIES OF BEET SUGAR INDUSTRIES.

The beet-sugar industry in the United States is steadily forging ahead, but so enormous is the consumption of sugar that, even with a much more rapid rate of growth, it will be many years before the production of sugar from this and other domestic sources will suffice to meet the home demand. In connection with these remarks, the following data from the *Sugar Beet* will throw some light on the condition of that industry:

"The total area devoted to beets for the seven beet-sugar factories in the United States (this includes the small output of Virginia) was in 1893–94, 19,647 acres, from which were obtained 195,895 tons of beets and 45,191,296 pounds of sugar, corresponding to a yield of 2,300 pounds of sugar per acre, and

an average of 230·7 pounds per ton of beets worked on an average extraction of 11·5 per cent. The average yield of beets per acre was 9·9 tons. Accepting these figures as a basis of calculation for the requirements of the Union, the consumption of sugar during 1894 was 2,024,648 tons, or 4,535,211,520 pounds. To obtain this sugar there would be needed at least 2,000,000 acres of land, if the yield be ten tons to the acre, and, if beets sell for $4 per ton, the money for these roots would represent the enormous sum of $80,000,000 that would be put into circulation among our farming population.

If we admit that farmers receive gratuitously fifty per cent. in weight of beets, furnished by the residual pulp as it leaves the process, this would be sufficient to feed not less than 2,000,000 head of cattle during the three winter months when fodders are most expensive. If we admit two pounds increase per head and diem, there would result 400,000,000 pounds of meat from a product that is now receiving only a limited amount of attention.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 19, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 19, 1895.

Mr. CHARLES BULLOCK, Vice-President, in the chair.

Present, seventy-nine members and eight visitors.

Additions to membership since last report, ten.

The Actuary reported, from the Board of Managers, that an application for the "Boyden Premium" had been received, and that, in accordance with the regulations, a committee of judges appointed by the Board had examined the memoir which accompanied the application, and had reported adversely. The sealed envelope received with the memoir, and supposed to contain the name and address of the applicant, had, in accordance with the rules made and provided for such cases, been destroyed in the presence of the Board. The memoir and report of the judges thereon were submitted with the Actuary's communication.

The action of the Board of Managers in the case was, on motion, unanimously approved.

The paper of the evening was read by Dr. J. F. Holt, on the "High-tension Storage Battery," manufactured by the Holt Electric Storage Company, under the patents of N. H. Edgerton.

The speaker described the special features of construction embodied in this battery, and exhibited specimens of the same adapted to various uses.

The subject was discussed by Messrs. Reed, Walter, Eldridge, Edgerton, and the author. The Chairman expressed the thanks of the meeting to Dr. Holt for his interesting communication. On Mr. Conard's motion, duly seconded, the subject was referred to the Committee on Science and the Arts for investigation and report.

The Secretary presented his monthly report, an abstract of which appears in the June number, and the meeting adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR MAY, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1895.

GENERAL REVIEW.

The average temperature for May, 1895, 60°·6, is 1°·4 above the average [59°·2] for the past seven years.

The highest recorded temperatures occurred on the 30th and 31st, and were as follows: Hollidaysburg, 110°; Lock Haven, 102°; Logania, 101°; and Carlisle, 100°.

The lowest were on the 17th: Smethport, 22°; Shingle House, 23°; Saegerstown, 24°; Wellsboro, 24°; and Dyberry, 24°.

High temperatures prevailed until the 11th, causing rapid growth to vegetation. On the night of the 12th–13th a severe frost occurred, which killed the greater portion of the grape crop and badly injured other fruits. This was followed on the 17th by another damaging frost and freeze, which added additional injury to fruit, corn and early vegetables. Damaging frosts occurred again on the 21st, 22d and 23d. Unusually high temperatures occurred during the balance of the month.

From January 1, 1895, to May 31, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 295°; at Erie, 327°, and at Pittsburgh, 373°.

For the same period the excess in precipitation, in inches, at Philadelphia, was 0·80; and deficiency at Erie 4·89, and at Pittsburgh, 4·49.

TEMPERATURE.

	Mean Temperature.	Mean Precipitation, Inches.
May, 1888	57°·6	4·24
1889	62°·0	5·91
1890	58°·8	6·71
1891	57°·5	2·12
1892	59°·5	5·70
1893	58°·0	5·54
1894	60°·8	8·88
1895	60°·6	2·68

The means of the daily maximum and minimum temperatures, 72°·5 and 48°·6, respectively, give a monthly mean of 60°·6, which is 0°·2 below the corresponding month of 1894.

The average daily range was 23°·9.

Highest monthly mean, 63°·6 at Immel Reservoir (Lycippus) and Pottstown.

Lowest monthly mean, 56°·6 at Shingle House.

Highest temperature recorded during the month, 110° on the 30th at Hollidaysburg.

Lowest temperature, 22° on the 17th at Smethport.

Greatest local monthly range, 85° at Hollidaysburg.

Least local monthly range, 53° at Erie.

Greatest daily range, 52° at Wilkes-Barre.

PRECIPITATION.

The average precipitation for the State, for the month, 2·68 inches, is 2·90 inches less than the average [5·58] for the past seven years.

The rainfall was generally well distributed and timely.

The largest monthly totals of rainfall in inches were: Wellsboro, 6·46; Cassandria, 4·66; Oil City, 4·22; Wilkes-Barre, 4·16; Pottstown, 3·89; and Frederick, 3·76.

The least were: Altoona, 0·80; Beaver Dam, 1·19; Immel Reservoir (Lycippus), 1·34; Greensboro, 1·55; Stoyestown, 1.70; and Brookville, 1·71.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 9; clear days, 13; fair days, 10; cloudy days, 8.

BAROMETER.

The mean pressure for the month, 30·07, is about ·07 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·36 at Philadelphia on the 1st, and the lowest 29·61 at Harrisburg on the 11th and Erie on the 26th.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Hollidaysburg, 7th, 8th, 11th, 26th; Le Roy, 7th, 8th, 11th; Towanda, 7th, 8th, 11th; Quakertown, 27th; Cassandria, 7th, 26th; Johnstown, 7th, 8th, 11th; Emporium, 7th, 8th, 26th; East Mauch Chunk, 8th; State College, 7th, 11th, 19th; Coatesville, 27th; Kennett Square, 27th; Westtown, 27th; Lock Haven, 4th, 7th, 8th, 11th, 27th; Saegerstown, 6th, 7th, 11th; Harrisburg, 8th, 11th; Uniontown, 6th, 7th; Huntingdon, 5th, 9th, 10th; Lebanon, 8th, 31st; Coopersburg, 11th, 27th; White Haven, 8th, 11th; Wilkes-Barre, 31st; Williamsport, 7th, 8th, 11th, 31st; Easton, 31st; Aqueduct, Logania, 8th, 11th; *Philadelphia* [Weather Bureau], 27th; [Centennial Avenue], 27th; Blooming Grove, 8th, 11th; Somerset, 7th, 11th; Lewisburg, 8th, 11th; Dyberry, 8th, 11th, 31st; Honesdale, 8th, 25th, 31st; Salem Corners (Hamlinton), 8th, 11th; South Eaton, 8th, 11th.

Hail.—Lock Haven, 4th; Williamsport, 12th.

Frost.—Gettysburg, 13th, 17th; Pittsburgh, 13th, 17th, 20th, 21st, 22d; Hollidaysburg, 13th, 17th, 20th, 22d; Le Roy, 13th, 16th, 17th, 20th, 21st, 22d; Towanda, 16th, 17th, 22d; Forks of Neshaminy, 17th; Quakertown, 16th, 17th, 22d, 23d; Cassandria, 14th, 15th, 17th, 18th, 20th, 22d; Johnstown, 13th, 15th, 17th, 22d, 23d; Emporium, 13th, 16th, 17th, 20th, 21st, 22d, 23d; East Mauch Chunk, 17th, 22d; State College, 13th, 17th, 22d; Coatesville, 17th, 22d; Kennett Square, 15th, 17th; Phœnixville, 13th, 15th, 17th; Westtown, 17th; Lock Haven, 13th, 17th; Saegerstown, 12th, 13th, 14th, 16th, 17th, 18th, 21st, 22d, 23d; Carlisle, 17th; Harrisburg, 17th, 22d; Edinboro, 12th, 21st; Uniontown, 13th, 17th, 22d, 23d, 28th; Chambersburg, 22d; Huntingdon, 17th, 22d; Lebanon, 17th, 22d; Coopersburg, 17th; Drifton, 21st; White Haven, 16th, 17th, 22d, 23d; Wilkes-Barre, 17th; Williamsport, 17th, 22d; Greenville, 13th, 17th, 18th, 21st; Pottstown, 17th; South Bethlehem, 17th; Easton, 17th; Aqueduct, Logania, 2d, 15th, 16th, 17th, 22d, 23d; *Philadelphia* [Weather Bureau], 17th; [Centennial Avenue], 17th; Blooming Grove, 16th, 17th; Shingle House, 13th, 16th, 17th, 20th, 21st, 23d; Selins Grove, 13th, 17th, 21st; Somerset, 10th, 13th, 17th, 18th, 22d; Wellsboro, 13th, 16th, 17th, 18th, 20th, 22d; Lewisburg, 17th, 20th, 22d; Dyberry, 2d, 3d, 13th, 16th, 17th, 20th, 21st, 22d, 23d, 29th; Honesdale, 13th, 14th, 16th, 17th, 22d, 23d; Salem Corners (Hamlinton), 13th, 14th, 15th, 16th, 17th, 18th, 22d; South Eaton, 16th, 22d, 23d; York, 17th.

Sleet.—Le Roy, 12th; Salem Corners (Hamlinton), 12th.

Coronæ.—Towanda, 4th, 5th, 30th.

Solar Halo.—Le Roy, 16th, 17th; Towanda, 15th, 18th; South Bethlehem, 17th; *Philadelphia*, [Weather Bureau], 17th; [Centennial Avenue], 2d, 11th, 17th, 24th; Wellsboro, 17th.

Lunar Halo.—Towanda, 3d; *Philadelphia*, [Weather Bureau], 7th.

Parhelias.—Le Roy, 3d.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1895.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1895.

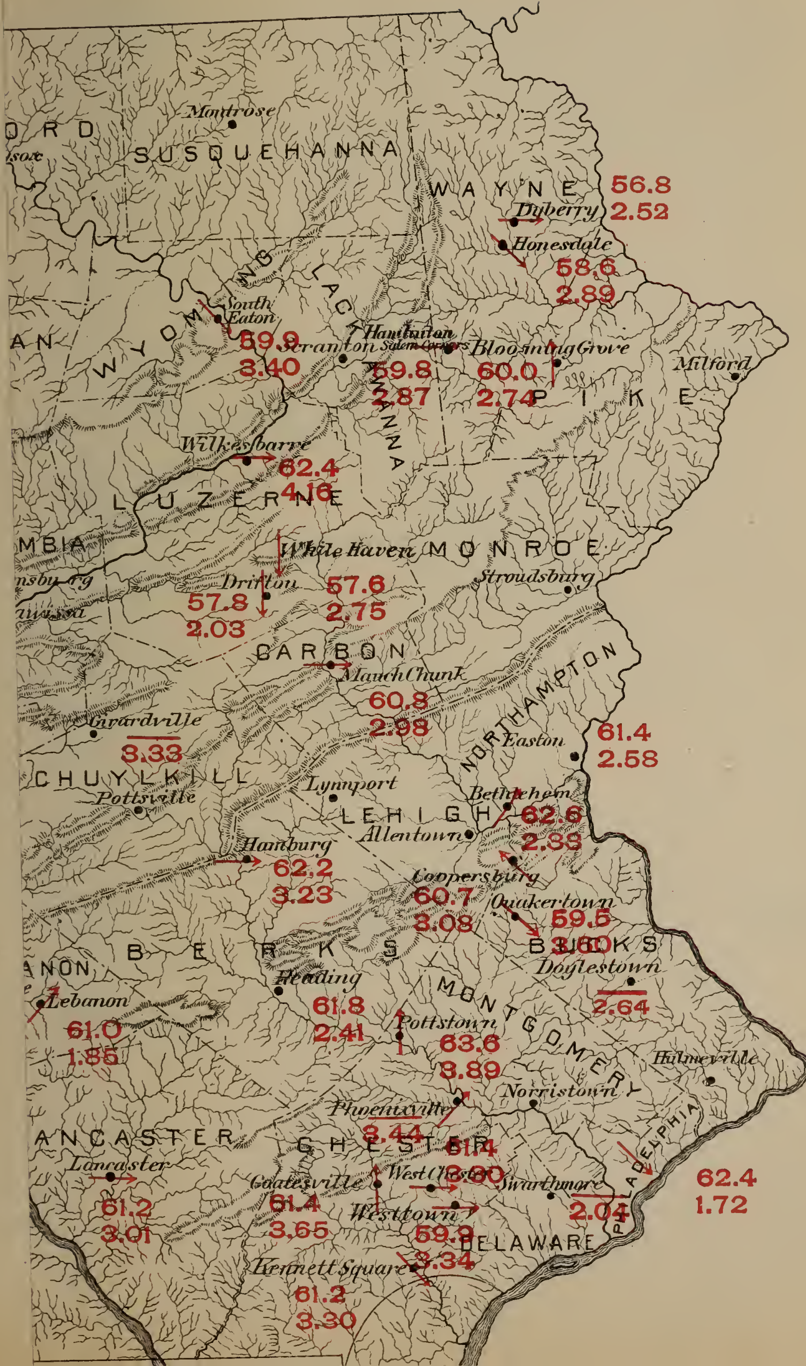
County.	Station.	Elevation above Sea Level (feet).	Temperature. Mean.	Temperature. Maximum. Highest.	Temperature. Maximum. Date.	Temperature. Minimum. Lowest.	Temperature. Minimum. Date.	Temperature. Mean of Maximum.	Temperature. Mean of Minimum.	Temperature. Daily Range. Mean.	Temperature. Daily Range. Greatest.	Precipitation. Total Inches.	Precipitation. Total Snowfall During Month.	Precipitation. Depth of Snow on Ground at End of Month.	Precipitation. Number of Days Rain or Snow.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction.	Observers
Adams,	Gettysburg,		60·9	94	30	35	17, 22	72·0	49·8	22·2	41	3·16	...		13	17	10	4	S	H. F. Buehler.
Allegheny,	Pittsburgh,	820	63·3	93	30	35	22	73·6	53·0	20·6	34	1·97	..	.	10	8	13	10	S	O. D. Stewart, W. B
Berks,	Hamburg.	380	62·2	96	30	33	17	73·9	50·4	23·5	40	3·23	...	..	7	5	16	10	W	William Shipe.
Berks,	Reading,[2]	280	61·8	...	..	...	.	...	.	...	...	2·41	...	..	11	..	..	..	...	Franklin Yager.
Blair,	Altoona (30 days),	1,181	65·0	95	31	37	22	75·7	54·3	21·4	41	0·80	...	..	6	..	..	..	...	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	61·8	110	30	25	22	77·7	45·8	31·9	52	2·39	...	...	9	16	7	8	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	59·0	91	31	28	13	70·4	47·7	22·7	34	3·24	...	...	10	15	6	10	SW	G. W. T. Warburton.
Bradford,	Towanda,	754	59·6	93	30	27	17	72·3	47·0	25·3	48	2·56	...	...	9	17	4	10	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy[1] (27 days),	304	60·7	.	...	...	...	.	...	...	...	2·70	...	...	9	16	..	11	N	J. C. Hilsman.
Bucks,	Quakertown,	536	59·5	95	30	29	17	71·7	47·3	24·4	41	3·60	...	..	8	11	12	8	NW	J. L. Heacock.
Cambria,	Cassandria	2,100	59·5	88	30	31	22	67·3	51·7	15·6	30	4·66	T	...	10	15	8	8	NW	A. H. Boyle.
Cambria,	Johnstown,	1,184	61·6	94	31	30	17	75·1	48·1	27·0	42	2·83	T	.	12	14	7	10	S	E. C. Lorentz.
Cameron,	Emporium,	1,050	60·0	98	30	27	17, 22	74·2	45·8	28·4	46	3·08	T	..	8	16	8	7	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	60·8	97	30	28	17	74·2	47·3	26·9	47	2·98	...	..	11	19	7	5	W	F. C. Wintermute.
Centre,	State College—																			
	Agricultural Experiment Sta.,	1,191	59·3	93	30	31	13	69·2	49·4	19·8	30	2·21	...	..	10	9	12	10	S	Prof. Wm. Frear.
Chester,	West Chester,	455	61·4	92	30, 31	38	17, 22	70·9	51·9	19·0	30	3·30	.	...	11	16	4	11	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	61·4	95	31	30	17	73·3	49·4	23·9	40	3·65	...	...	8	13	14	4	S	W. T. Gordon.
Chester	Kennett Square,	275	61·2	94	31	34	17	72·9	49·5	23·4	37	3·30	..	...	12	14	8	9	NW	B. P. Kirk.
Chester,	Phœnixville,‡	190	...	...	...	35	17, 20	...	...	..	...	3·44	...	...	9	11	8	12	SW	T. Knowles Perot.
Chester,	Westtown (30 days),	350	59·9	92	31	34	17	69·9	49·9	20·0	35	3·34	...	.	8	7	16	7	W	John D. Carter.
Clearfield,	Grampian,†	1,450	59·6	94	31	26	13	72·0	47·1	24·9	38	2·38	...	.	10	7	15	9	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	63·2	102	30	30	22	...	...	...	...	2·35	...	...	9	20	6	5	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	58·7	94	5	24	22	75·2	42·2	33·0	48	3·60	T	..	8	10	10	11	NW	J. G. Apple.
Cumberland,	Carlisle,	480	61·9	100	30	32	17	73·0	50·8	22·2	39	2·34	...	...	10	16	9	6	S	J. E. Pague.
Dauphin,	Harrisburg,	480	62·0	95	30	37	17	71·0	52·0	19·0	35	1·98	...	...	11	21	3	7	W	F. Ridgway, W. B.
Delaware,	Swarthmore—																			
	Swarthmore College‡.	361	...	...	...	...	...	...	...	...	...	2·04	...	...	5	..	.	..	..	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	58·0	89	5	26	12	...	...	...	...	..	...	.		..	..	..	W	C. F. Sweet.
Erie,	Erie,	1,400	59·0	85	31	32	13	67·0	51·0	16·0	36	2·58	...	...	9	12	13	6	SW	P. Wood, W. B.
Fayette,	Uniontown (29 days),	681	59·2	90	5	29	22	70·7	47·7	23·0	36	2·07	...	...	7	11	16	2	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	60·0	96	30	30	17	72·4	47·6	24·8	42	2·39	...	...	11	8	9	14	W	J. C. Boggs.
Huntingdon,	Huntingdon—																			
	The Normal College,	650	61·3	98	30	25	14	76·5	46·1	30·4	48	3·01	...	...	8	2	23	6	SE	Prof. W. J. Swigart.
Lancaster,	Lancaster—																			
	Franklin and Marshall Col'ge,	413	61·2	93	30, 31	36	22	71·8	50·6	21·2	33	3·01	..	...	11	16	8	7	W	A. V. Heister.
Lebanon,	Lebanon,	458	61·0	96	30	32	17	72·6	49·3	23·3	40	1·85	...	...	11	10	12	9	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	60·7	89	30, 31	35	17	70·5	50·9	19·6	32	3·08	...	...	11	13	13	5	SE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	57·8	93	31	29	17, 21	71·2	44·5	26·7	50	2·03	...	.	6	7	12	7	N	J. R. Wagner.
Luzerne,	White Haven,		57·6	91	30, 31	26	17	70·4	44·7	25·7	43	2·75	...	...	5	9	17	5	S	C. M. Driggs.
Luzerne,	Wilkes-Barre,	575	62·4	97	30	30	17, 21	77·8	47·0	30·8	52	4·16	...	...	7	15	6	10	W	A. W. Betterly.
Lycoming,	Williamsport,		61·5	96	30	33	17, 22	72·1	50·9	21·2	42	3·37	...	...	9	18	8	5	W	G. D. Snyder, C. E.
McKean,	Smethport,	1,500	56·9	94	30	22	17	71·8	42·0	29·8	46	2·12	...	...	10	10	14	7	SW	Armstrong & Brownell.
Mercer,	Greenville—																			
	Thiel College,	1,000	58·6	94	30	25	21	72·2	45·0	27·2	40	2·75	...	...	7	21	2	8	...	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	63·6	97	31	36	17	74·5	52·6	21·9	36	3·89	...	...	6	14	13	4	S	Charles Moore, D.D.S.
Northampton,	South Bethlehem,	339	62·6	97	30	36	17	74·8	50·5	24·3	39	...	...	...	...	13	9	9	SW	T. Merriman.
Northampton,	Easton—																			
	Lafayette College,	325	61·4	93	30, 31	33	17	72·7	50·1	22·6	38	2·58	...	...	8	17	6	8	...	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	63·2	101	30, 31	31	17	75·2	51·2	24·0	46	2·06	...	...	11	13	9	9	SE	Richard Callin.
Philadelphia,	U. S. Weather Bureau.	117	62·4	94	30	40	13	71·5	53·3	18·2	29	1·72	...	...	9	8	17	6	NW	L. M. Dey, W. B.
Philadelphia,	1529 Centennial Avenue,	120	63·0	96	31	40	2, 13	73·0	52·9	20·1	31	2·03	...	...	8	8	17	6	NW	John Comly.
Pike,	Blooming Grove,*[1]	...	60·0	94	30	36	13	..	..	...	...	2·74	...	..	8	5	21	5	S	John Grathwohl.
Potter,	Shingle House,	1,475	56·6	93	30	23	16, 17	71·6	41·7	29·9	48	2·65	...	...	8	18	3	10	NW	H. L. Pearsall.
Snyder,	Selins Grove,	455	61·2	96	31	29	17	75·9	46·5	29·4	45	3·26	...	...	10	..	22	9	SW	J. M. Boyer.
Somerset,	Somerset (30 days),	2,250	57·2	92	30	25	17	71·5	42·8	28·7	40	1·88	...	...	3	3	19	8	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	55·8	92	30	24	17	.	...	...	...	6·46	...	...	13	13	3	15	S	H. D. Deming
Union,	Lewisburg	450	61·2	99	30	30	17	74·7	47·7	27·0	46	3·66	...	...	9	12	10	9	S	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	56·8	90	30, 31	24	17	71·1	42·4	28·7	51	2·52	...	...	7	14	10	7	W	Theodore Day.
Wayne,	Honesdale,	1,000	58·6	91	30	28	17	70·3	46·8	23·5	40	2·89	...	...	11	16	9	6	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	59·8	96	31	30	13, 22	70·5	49·0	21·5	37	2·87	T	..	14	9	9	13	W	T.B. Orchard, M D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	63·6	92	31	37	13	72·5	54·7	17·8	41	1·34	...	..	6	..	..	..	...	Murray Forbes.
Wyoming,	South Eaton,	660	59·9	90	30, 31	30	22	71·7	48·1	23·6	42	3·40	...	..	7	17	3	11	NW	B. M. Hall.
York,	York,	385	61·4	95	30	34	17, 22	72·7	50·1	22·6	35	2·73	.	..	13	15	11	5	W	Mrs. L. H. Grenewald.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers. [1] Mean temperatures, $7 + 2 + 9 + 9 \div 4$ [2] Mean temperature $8 + 8 \div 2$.
† No records. ‡ Records incomplete.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Delaware Basin																			
Bethlehem,									·03			·49		·86					
Blooming Grove,											‡	·68		1·00					·03
Browers Lock,												·56		·46		·05		·09	
Coatesville,									·12			·63		·77		·01		·16	
Coopersburg,	·02					·01			·02			·80		·90	·02	·01		·01	
Doylestown,												·34		·28				·03	
Dyberry,								·39				1·05		·45					·06
Easton,											‡	·78		·89					
Forks of Neshaminy,	·06					·02						·28		·31		·05		·10	
Frederick,												·57		·70				·04	
Hamburg,								·51				·52		·94				·06	
Honesdale,								·20	·02			·92	·10	·46	·12				·08
Kennett Square,	·04					·02	·02		·05			·38		·95		·05		·14	
Lansdale,												·53		·25				·19	
Mauch Chunk,							·05	·05	·03	·01		·93		·87				·02	
Ottsville,						·01						·55		·50				·03	
Philadelphia, a†	·03					·02						·14		·22				·21	
Philadelphia, b,	·04											·17		·30				·20	
Phœnixville,	·03					·02				·33	·55			·51				·10	
Point Pleasant,												·47		·23					
Pottstown,	·05							·07				·75		1·45					
Quakertown,	·02							·03				·74		·97				·03	
Reading,	·01							·01	·15			·45		·83				·01	·01
(Salem Corners) Hamlinton,	·22								·27		‡	1·03		·45	·18				‡
Seisholtzville,	·02							·10					·85	·83					·06
Smith's Corner,												·52		·28				·04	
Swarthmore,												·21		·31				·02	
West Chester,	·10					·02	·01		·07			·27		·80		·03		·12	
Westtown,	·05								*			·30		·65		·04		·13	
White Haven,								·19				1·06		·60					
Susquehanna Basin.																			
Altoona,									·03			·45		·12					
(Aqueduct) Logania,								·14	·04		·17	·18		·14				·04	·49
Carlisle,	·08							·41			‡	·16						·04	·30
Drifton,					*					·39	·46	*					·21		*
Emporium,							·45	·84			·34			·15					·20
Gettysburg,	·02							‡	1·50			·15		·11		·04		·06	·15
Girardville,											·80	·75		·64			·05	·10	·10
Grampian,							·78	·10	·18		·45			·38					·18
Harrisburg,†								·26	·32			·08		·10				·06	·38
Hollidaysburg,								1·13			·33	·32		·20					·05
Huntingdon,								·85	·07		·85			·23					·31
Lancaster,								·38			‡	·40	‡	·47			·12		·06
Lebanon,								·31	·25			·22		·28				·02	·15
Le Roy,	·02						·05	·73			·60	·50		·25					·48
Lewisburg,	·08							·47			1·26	·48		·28					·46
Lock Haven,				·15			·16	·10			·60			·15					·31
Selins Grove,								·11			·50	·18		·26					·65
South Eaton,								·16			·51	1·33		·44					·25
State College,	·13							·13			·48	·39		·19					·26
Towanda,							·03	·47			·40	·62		·25					·34
Wellsboro,							1·74	·20			·05	·35		1·12	·35	·10			·50
Wilkes-Barre.								·70			‡	1·95		·35					
Williamsport,							1·07	·29			·65			·43					·34
York,	·02							·95				·15		·10	·05	·02		·04	·33

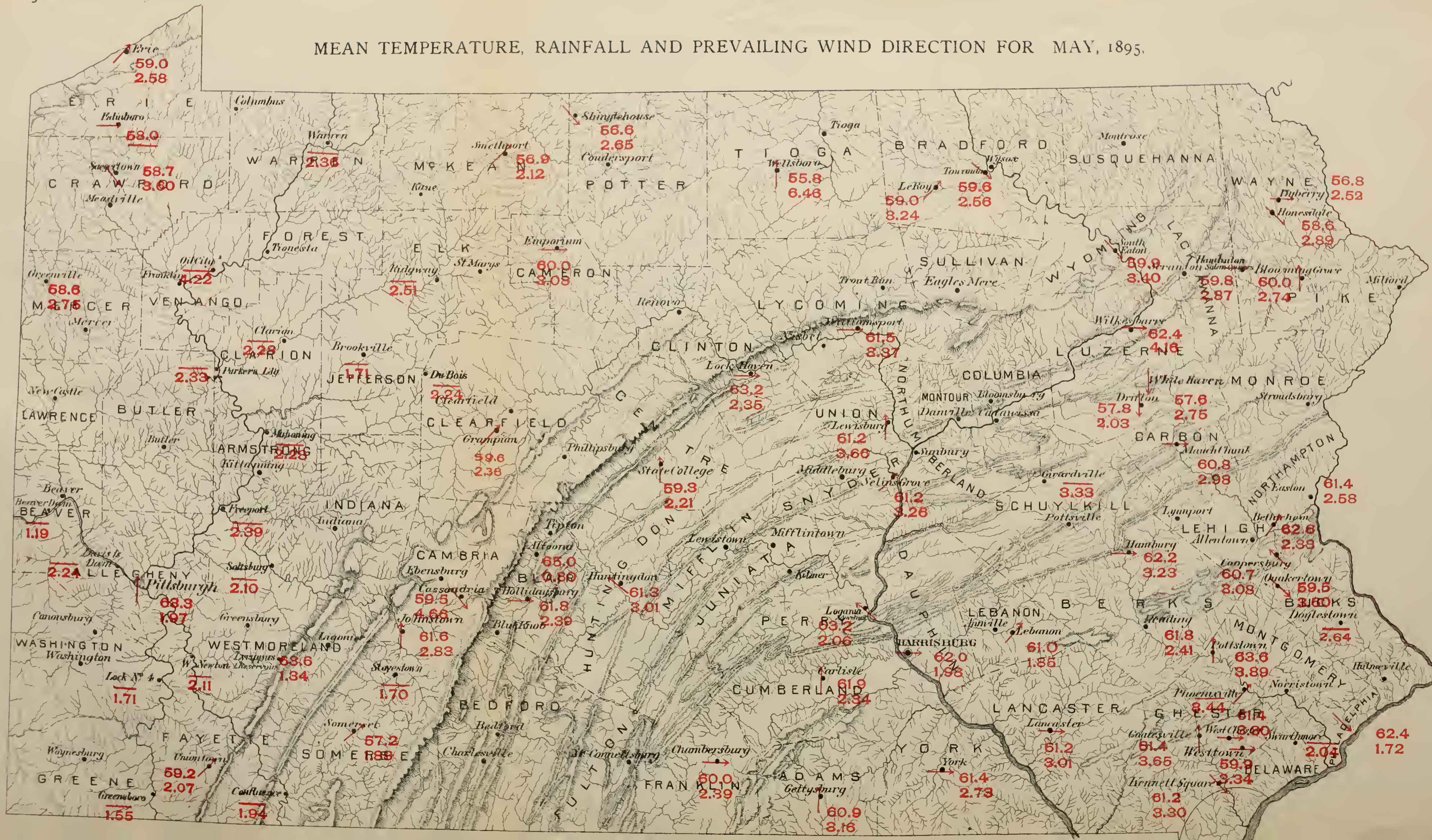
† U. S. Weather Bureau Stations. * Missing. ‡ Amount included in measurement following.

FOR MAY, 1895.



SUSQUEHANNA
Montrose
WAYNE
Dyberry
56.8
2.52
Honesdale
58.6
2.89
WYOMING
South Eaton
59.9
3.40
LACKAWANNA
Scranton
Hamilton
Salem Corners
59.8
2.87
Blooming Grove
60.0
2.74
PIKE
Milford
Wilkesbarre
62.4
4.16
LUZERNE
MONROE
White Haven
Stroudsburg
Drifton
57.8
2.03
57.6
2.75
CARBON
Mauch Chunk
60.8
2.98
NORTHAMPTON
Easton
61.4
2.58
Girardville
3.33
SCHUYLKILL
Pottsville
Lynnport
LEHIGH
Bethlehem
62.6
2.33
Allentown
Hamburg
62.2
3.23
Coopersburg
60.7
3.08
Quakertown
59.5
BERKS
BUCKS
Doylestown
2.64
Reading
61.8
2.41
Lebanon
61.0
1.85
MONTGOMERY
Pottstown
63.6
3.89
Holmesville
Norristown
Phoenixville
3.44
LANCASTER
CHESTER
Lancaster
61.2
3.01
Coatesville
61.4
3.65
West Chester
Westtown
Swarthmore
2.04
PHILADELPHIA
62.4
1.72
DELAWARE
Kennett Square
61.2
3.30

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR MAY, 1895.



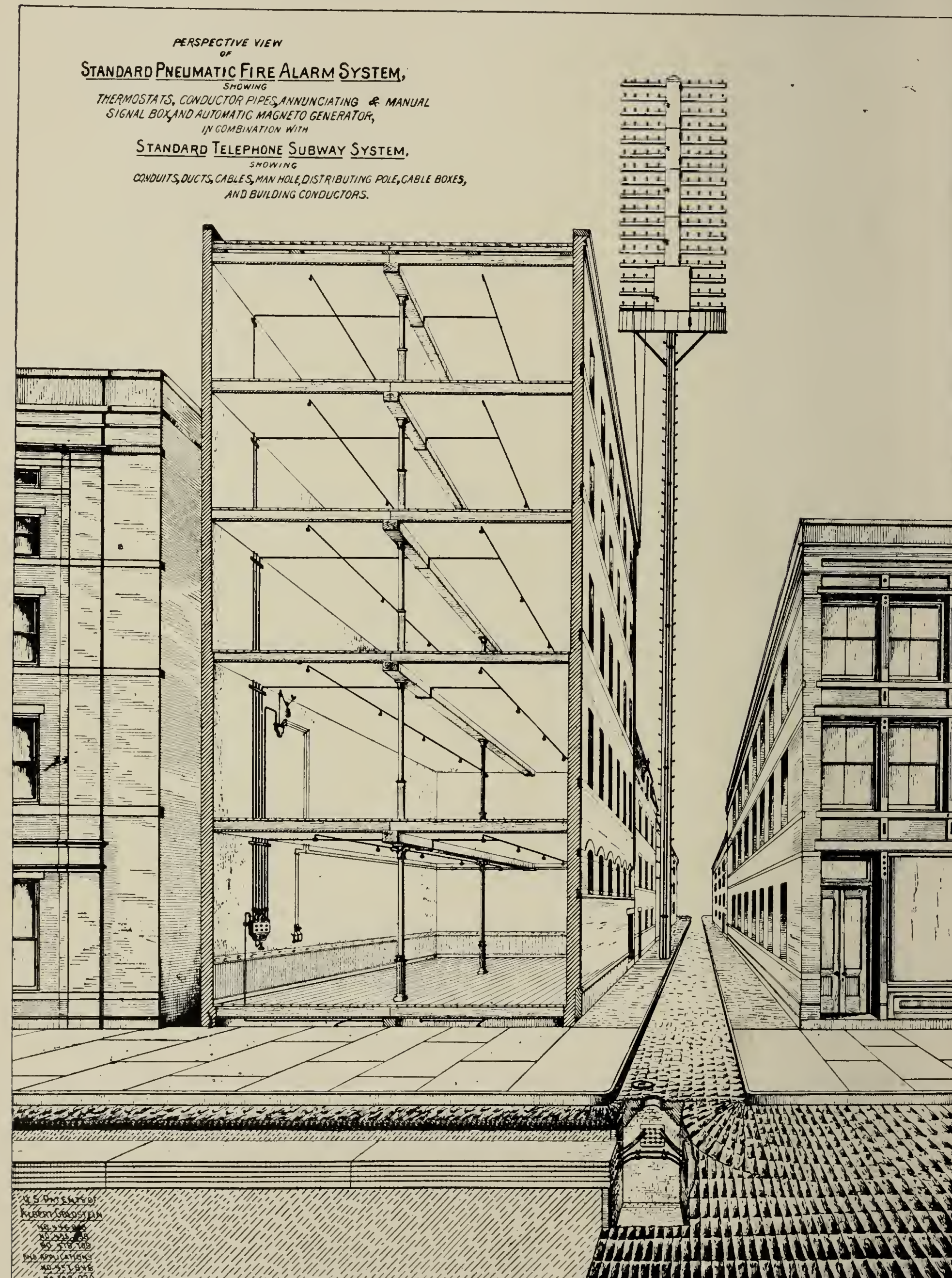

PERSPECTIVE VIEW
OF
STANDARD PNEUMATIC FIRE ALARM SYSTEM,
SHOWING
THERMOSTATS, CONDUCTOR PIPES, ANNUNCIATING & MANUAL
SIGNAL BOX AND AUTOMATIC MAGNETO GENERATOR,
IN COMBINATION WITH
STANDARD TELEPHONE SUBWAY SYSTEM,
SHOWING
CONDUITS, DUCTS, CABLES, MAN HOLE, DISTRIBUTING POLE, CABLE BOXES,
AND BUILDING CONDUCTORS.
U. S. PATENTS OF
ALBERT GOLDSTEIN
AND APPLICATIONS

PLATE A.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXL. AUGUST, 1895. NO. 2

THE PNEUMATIC FIRE-ALARM TELEGRAPH SYSTEM.

[*Being the report of the Franklin Institute through its Committee on Science and the Arts, on the invention of Albert Goldstein.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 2, 1895.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating Goldstein's Fire-Alarm Telegraph System, reports as follows:

This device is entirely pneumatic and mechanical within the building protected, and embodies a magneto-electric machine for the transmission of the telegraphic alarm to the fire-department headquarters, and which is covered by the following patents:

Nos. 213,536· 242,803; 253,133; 446,863; 455,038; 479,909; dated respectively, March 25, 1879; June 14, 1881; January 31, 1882; February 24, 1891; June 30, 1891; July 26, 1892.

The system consists essentially of three parts, viz.: A thermostat, which acts under the influence of the heat of a fire near it; an annunciator, which receives the alarm from the detector or thermostat, and indicates it by visual room or floor signal and the ringing of a mechanical bell; and a transmitter, which is also actuated by the thermostat, and transmits the alarm by wire to a predetermined station; all these connected by closed pipes within the building.

The thermostat consists of a cylinder in which is a washer of asbestos coated with paraffine, and beneath the washer a loose-fitting piston, which receives the pressure of a spiral steel spring (piano wire), which spring is held under compression by a rod, the lower end of which is retained by two halves of a disk, which are held together by a solder which melts at a temperature of 150°.

When the thermostat is subjected to this temperature, the two halves of this disk part, releasing the rod and the spring, which, by its upward thrust on the piston and washer, with a quick impulse, drives the air in the cylinder through the pipe, producing a corresponding impulse upon a small bellows or diaphragm in the receiver. There may be many of these thermostats on the same floor pipe, and the pressure of an alarm is prevented from being expended in them by check valves, which yield to pressure from within but resist it from without the cylinders. The washer, saturated with paraffine, and fitting tightly in the cylinder, is hermetically sealed to it by the paraffine being melted around its edges, and is absolutely air-tight in its upward motion, in which it is facilitated by the softening of the paraffine from the heat to which the cylinder is subjected externally.

The pipes from each room or floor respectively, carrying a sufficient number of thermostats, are grouped together where they reach the annunciator, and the latter is connected by one pipe to the transmitter.

The annunciator contains a clockwork, adapted when released to ring a mechanical gong; a number of shutters, adapted when dropped to designate rooms or floors in the building; and a number of bellows connected to the respective pipes, adapted when actuated by an impulse of air from

a detector to drop the proper shutter and release the clock-work, thus ringing the local alarm and visually indicating the location of the fire. This local alarm runs for nearly fifteen minutes, and is for the purpose of alarming the occupants if present, and also for calling attention of the firemen, when they respond, to the annunciator, which indicates the particular location of the fire. For that purpose it is located preferably just within the main entrance of the building.

The transmitter consists essentially of a magneto-electric machine, impelled by a weight, which is released by an impulse of air from any thermostat in the building, and is electrically connected by wire with the central exchange of the local telephone company.

A wheel geared to the armature of this machine is furnished with contact springs, by which the number of the machine is telegraphically indicated in the usual way.

Thus, when any thermostat in a building protected by this apparatus is raised to a temperature of 150°, the fusible solder is melted, its spring is released, and its paraffined washer is driven up, sending an impulse of air to the annunciator and transmitter simultaneously; the former rings a bell, showing that there is a fire in the building, and drops a shutter showing the room or floor in which the fire exists. The shutter remains dropped until the firemen come, and at the same time the transmitter sends an alarm to the fire department headquarters, calling out the fire department and telegraphically indicating the building.

The transmitter is connected preferably to the existing telephone wire in the same building, or if there be none, to one adjacent to it; because these wires, being in constant use, are less liable to be out of order than those used for fire-alarm purposes only, and comparatively rarely tested. It is furnished with a device by which, when it is set in action from the operation of a detector, it automatically cuts out the telephone connection in the building and makes connection for itself, sending its alarm to the telephone exchange. These alarms are readily distinguishable by the telephone operator at the exchange, not only because of their marked

difference in tone from that of the ordinary magneto calls, but also because the telegraphic fire alarm number of the transmitter is audibly communicated fifteen times successively, in regular periodic impulses, impossible to misunderstand.

Upon the operator distinguishing the first one or two successive signals, or, in fact, merely recognizing their character, he plugs the line into the telephone line of the fire department, without moving from his seat in front of the switchboard, thereby making the special building conductor continuous all the way to the fire department. In that manner the alarms are transmitted direct to the fire department, notwithstanding that either of the two lines may have been in use when the automatic alarms started to come into the exchange. The transmitter communicates its fifteen successive signals in a period of two minutes, and at the end of that or any predetermined period, it automatically cuts out its own connection at the building, thereby restoring the telephone instrument to its normal connection with the line.

The alarms are distinguished at the telegraph bureau of the fire department by being printed upon a self-starting register, which records the impulses of current corresponding with the assigned fire alarm numbers of the transmitters in the usual way.

In cities where there are no telegraph operators employed at the fire department headquarters and where automatic repeaters are used in substitution, the alarms are caused to work directly through such automatic repeaters by extending any one of the city's fire-alarm circuits into the local telephone exchange and connecting a special type of relay direct to such city fire-alarm circuit, and upon receipt of alarms by the telephone operator, the latter can shunt the same into the city circuit by merely moving a switch connecting the subscriber's line with such special relay. If necessary, even this simple operation on the part of the telephone operator may be dispensed with, by providing automatic switches in place of manual switches, the former energized by electro-magnets wound to correspond with

the fire-alarm transmitters in the building, as, for example, a direct current instead of an alternating current, so as to be unaffected by impulses of alternating current from the use of the common type of magneto call movements used by telephone subscribers for the purpose of ringing up the exchange.

In relation to the state of the art in general, the system above described presents the following material advantages.

(1) It avoids the use of electric batteries in the various buildings and the constant attention they require to sustain them, and substitutes purely mechanical power that becomes operative only from the heat of a fire.

(2) It avoids the use of electric wires within the buildings and their attendant breakage and displacement, and substitutes iron pipe conductors, the same being as durable and permanent as the ordinary gas piping of a building.

(3) It avoids the use of the common type of electro-contact thermostats, which are variable and erratic under practical conditions, as they depend upon minute adjustments that appear to be impossible to be maintained with reliability and uniformity, and substitutes purely mechanical thermostats, rendered operative by the melting of fusible solder.

With regard to the transmission of the telegraphic alarms from the buildings to the fire department, the use of magneto-electric machines and existing telephone conductors presents the following advantages:

(1) It avoids the maintenance of the necessary closed-circuit and open-circuit batteries at a central station and the equipment of recording and repeating instruments at such point.

(2) It avoids the use of private metallic circuits, where two coincident line troubles cut off communication from all buildings located between such two foreign line troubles.

(3) It avoids the constant liability of signals interfering with each other by coming in together on the same circuit, and thereby conflicting and being rendered unintelligible.

(4) It avoids the use of overhead wires and their main-

tenance contrary to the regulations of the city authorities, and in many instances against the wishes or even without the knowledge of the owners of the buildings to which these wires are attached.

On the whole, the system in brief presents the following affirmative advantages:

(1) A purely mechanical local power.

(2) A purely mechanical thermostat.

(3) Iron pipe conductors.

(4) A purely mechanical annunciator.

(5) A purely mechanical electro-transmitter.

(6) An independent (underground) circuit, for each building, constantly used, and for that reason constantly tested.

(7) Either a slight manual operation at the exchange to make the signal go direct to the fire department, without the delay of re-transmission, or automatic switches in place of any operation whatever by operators.

The system in question, both in its broad conception and mechanical execution of details, evidences a marked intelligence and discrimination, in consideration of which, and of the beneficial results demonstrated by many practical tests, the Institute recommends the award of the John Scott Legacy Premium and Medal to Albert Goldstein, for his pneumatic fire-alarm telegraph system.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 6, 1895.

JOS. M. WILSON, *President*.
WM. H. WAHL, *Secretary*.

Countersigned by
SAMUEL SARTAIN, *Chairman*.

Award confirmed by the Board of Directors of City Trusts, June 10, 1895.

APPENDIX.

To illustrate the preceding report, *Plate A* represents a perspective view of a standard pneumatic fire-alarm equipment as installed in a building, showing (1) the thermostats, (2) the iron pipe conductors, (3) the annunciating box, and (4) the electro-transmitter or generator. The latter is con-

nected to the local telephone circuit by three wires, so as to be short-circuited under ordinary conditions (in order to avoid making any resistance in the circuit); but upon the operation of a thermostat, the relative positions of the generator and telephone become reversed, thereby short-circuiting the latter, but only for the predetermined interval in which the telegraphic alarms are transmitted.

To indicate the security of such circuits, as afforded by the modern type of telephone subway construction, there is shown in the same plate a perspective view of the individual metallic circuit as it enters the cable box on the distributing pole, and thence goes underground, as shown by the view of the cables in the man-hole, including ducts and conduits. In addition to the permanence of such construction it possesses the advantage of the frequent test of each circuit as afforded by the almost constant telephonic communication over same, without, however, such use interfering with the automatic transmission of telegraphic alarms, when necessary.

Plate B shows a generator of the alternating current type, the alarms from which are received by the operator at the exchange (and re-transmitted), as distinguished from purely automatic transmission, when direct current generators are used at the subscriber's building, and correspondingly wound relays or automatic switches at the exchange.

Plate C represents the local annunciating box with separate pipes and shutter drops to correspond with the respective floors or apartments. A circuit-breaking device of the usual type is contained therein, so that it can be connected in series with any existing closed circuit, such as a city fire-alarm circuit, district telegraph, or private metallic circuit running to a central station, either in addition to the telephone exchange connection, or independent of it, where for any reason the latter cannot be procured.

Fig. 1 is a vertical section of the thermostat or actuating device in the normal condition; *Fig. 2* is a vertical section of same in operative connection, and *Fig. 3* is a side elevation in perspective. The respective parts are lettered in detail, as follows: *A* is a small cap that fits over the outlet

or nozzle, and has inverted lugs for the purpose of retaining the contained check-valve, when the latter is forced outward from the internal air pressure; *B* is the nozzle, with stand-

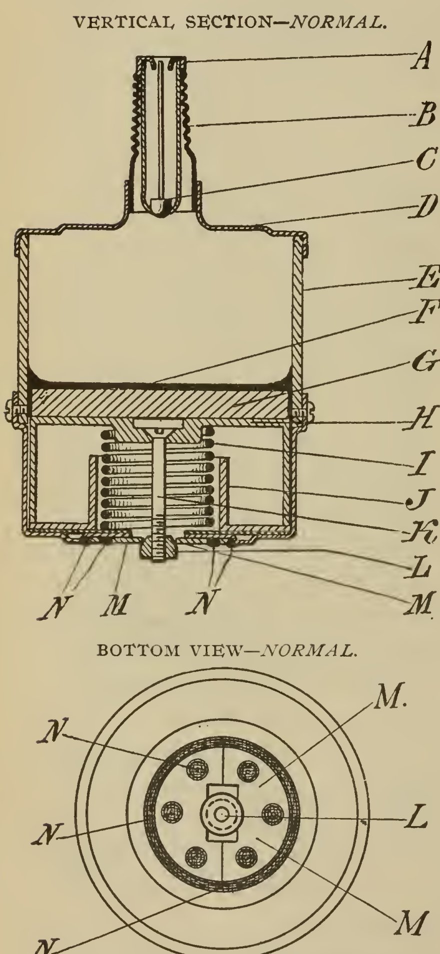


FIG. 1.

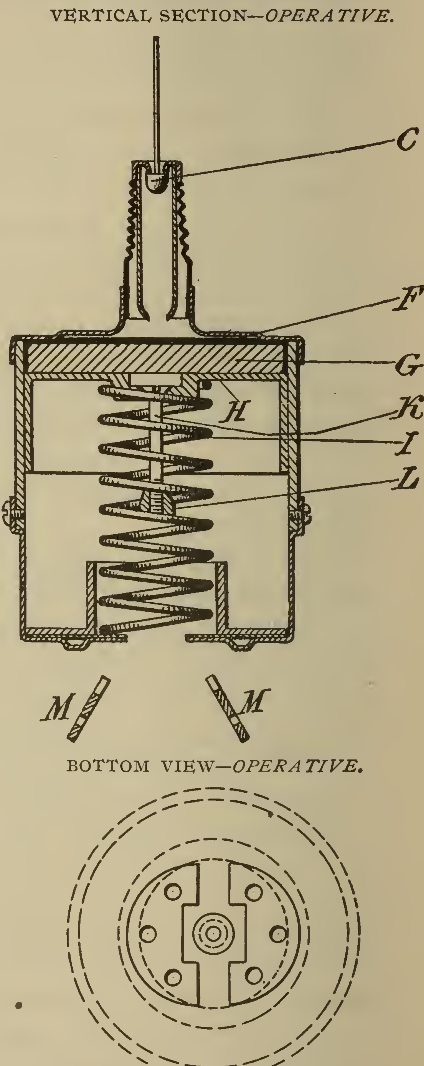


FIG. 2.

ard pipe thread (1-8) for screwing the thermostat into pipe fitting; *C* is a gravity check-valve, which yields to the internal air pressure, but resists it from any other thermo-

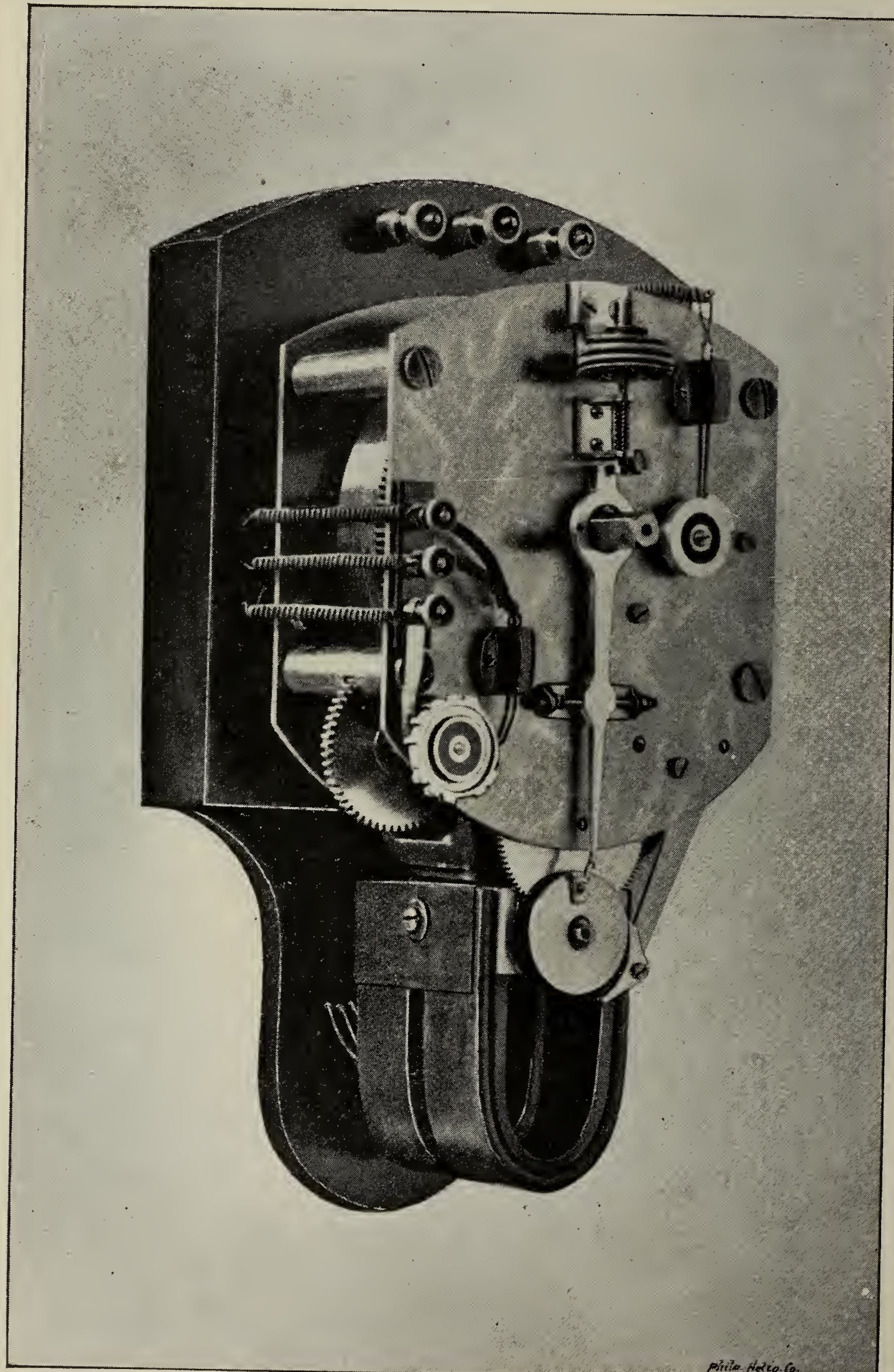


PLATE B.—AUTOMATIC MAGNETO GENERATOR.
(DIMENSIONS OF WORKS, WITHOUT CASE, 7 x 13 INCHES.)

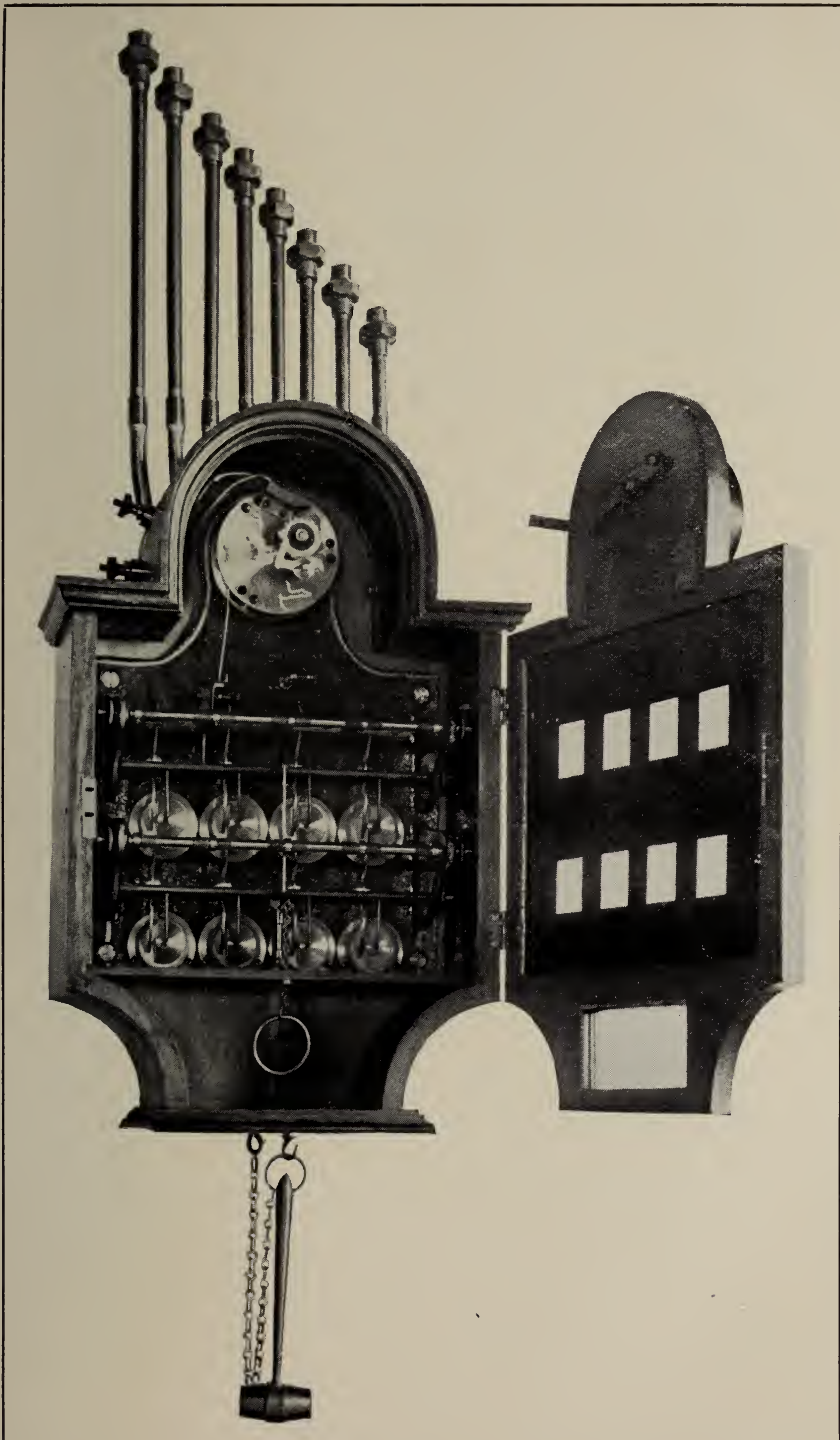


PLATE C.—AUTOMATIC ANNUNCIATING AND MANUAL SIGNAL BOX.
(DIMENSIONS OF WORKS, WITHOUT CASE, 9 X 13 INCHES.)

stat connected to the same conductor pipe; *D* is the top cap over the air cylinder, and is brazed at the joints; *E* is the cylinder or air chamber of thermostat, the contents of which are normally at atmospheric pressure; *F* is a paraffine-wax seal, which fuses from the external heat in case of fire, and thereby lubricates the piston motion, as well as renders the same air-tight; *G* is an asbestos washer or packing, boiled in melted paraffine before use; *H* is a loose-fitting piston or plunger, cylindrical in shape, so as to be

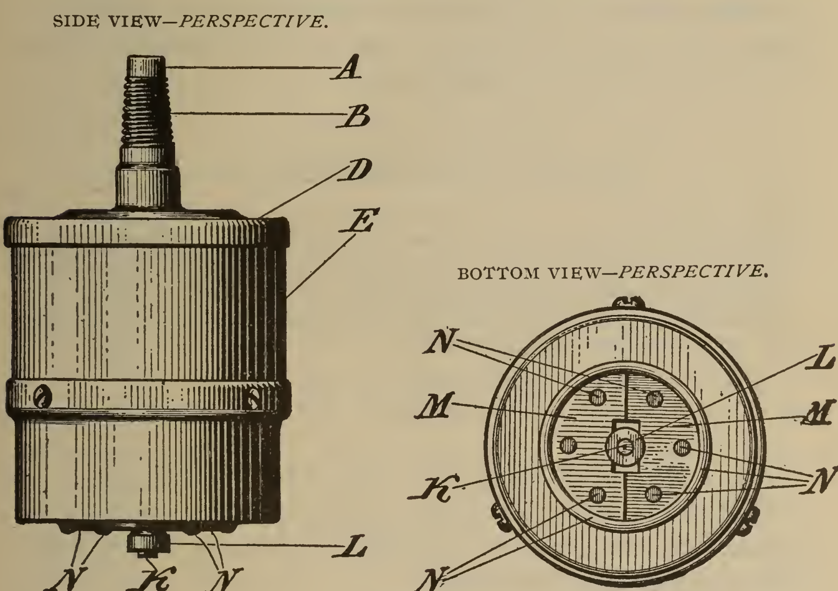


FIG. 3.

guided in movement; *I* is a normally compressed steel (piano wire) spring, specially drawn and tempered for the purpose; *J* is a cylindrical guide for the same; *K* is a vertical screw or rod in the center of the spring *I*, and keeps the latter under compression between the piston *H* at the upper end and a tapered nut *L* at the lower end, the latter being held at right angles, like a shoulder, by means of two halves of a disk *M*, which are retained in this position by being soldered to the base of the thermostat with the fusible metal *N*. When the resistance of the latter is

diminished by the heat of an incipient fire, the two halves of the disk *M* spread apart from the force of the shearing strain exerted by the wedge or tapered nut *L*, thereby permitting the latter to pass between, and the spring *I*, consequently, to push the piston and washer forward and compress the contained air of the cylinder. The possibility of premature rupture of the fusible solder *N* is resisted by a circular ridge or abutment at the circumference of the two halves of the disk *M*, while, on the other hand, the constant shearing strain of the wedge or tapered nut *L* serves to make the solder sensitive to the abnormal temperature which it is designed to indicate.

SANITARY ENGINEERING.

By Wm. Paul Gerhard, C.E., Consulting Engineer for Sanitary Works; Mem. Amer. Public Health Association; Amer. Forestry Association; German Samaritan Society; Corresp. Mem. Amer. Inst. of Architects; Honorary Consulting Sanitary Engineer to the Department of Health of the City of Brooklyn, N. Y., etc.

[*Concluded from p. 68.*]

THE LAYING-OUT OF CITIES AND TOWNS.

The municipal and sanitary engineer's services become of paramount value in the laying-out of cities and towns. This complex problem arises:

(1) When new towns are founded.

(2) When, owing to the tendency of men to congregate in cities, these grow so quickly as to require the extension of their limits by the addition of new outlying districts.

(3) When the alteration of the older parts of a city becomes necessary, owing to the increased internal traffic which requires the extension or widening of streets, or when, as in European cities, the abolishment of fortifications in old towns and the tearing down and planing off of fortified walls causes a sudden growth and expansion of the town, and calls for a reconstruction of its narrow streets, simultaneously with the building up of its outer districts.

In all such cases the actual work of extension, in whole or in part, should be carried out under a general, well-considered plan, and under the guidance of certain practical as well as æsthetic principles. We must confess, at the outset, that little work of the kind has, in the past, been done in the United States in the way suggested, for, as a rule, American cities grow in a haphazard fashion and often so quickly as to render the study of the problem and the preparation of plans out of the question.

For a learned and systematic consideration of the practical and æsthetic principles involved in town building and street planning we are largely indebted to the works of my esteemed former teacher of civil engineering, Professor R. Baumeister, of the Carlsruhe Polytechnic School, to the elaborate work on the same subject by Baurath J. Stübben, City Engineer of Cologne, Germany, and to the studies and labors of two eminent German architects, Herr Camillo Sitte, of Vienna, and Professor Karl Henrici, of the Polytechnic School at Aachen. While Baumeister and Stübben deal with the subject more from an engineering and health point of view, Sitte and Henrici discuss street architecture chiefly from the position of the æsthetic and the landscape architect.

In matters of street architecture there is a vast difference between European and American cities. The former are, as a rule, much more interesting, the sights are grander, the street perspectives are more beautiful and ever-changing, the impressions of the vivid and varied traffic are more lasting; monumental buildings are placed to better advantage; waterways are more picturesque, and more glimpses are afforded of gardens, parks and rows of trees used for the ornamentation of the streets. Compared with European streets, the American city streets lack architectural effects; we have too many dull, stupid and monotonous rows of houses, each house being identical with its neighbors, and in the business portions the ugly sky-scrapers of many stories shut out the light of day, the blue of the sky and the pure air of heaven, while there is a lack of prospects and outlooks of ever-varying views, and of expressions and im-

pressions of beauty. In all this, I firmly believe, we have very much to learn from the older cities of Europe.

The planning of extensions of existing cities and the laying out of new towns require a very careful consideration of the numerous engineering works located both above and below the streets, and of the constructive, sanitary and æsthetic features of streets, squares and buildings. Broadly speaking, the requirements relate to traffic, to building and to sanitation. It is fortunate that in street planning and street architecture, the æsthetic and art requirements coincide with the requirements of hygiene. Everything in this line which helps to embellish a city has also sanitary advantages. I, therefore, crave your pardon, if, in the following, I mention matters which at first blush may appear to you to be more of an architectural nature, or belonging to landscape rather than to sanitary engineering.

In developing the plan of a city we should consider the mode of living of the inhabitants and the character of its habitations and other buildings. Regarding dwelling houses we may distinguish the open or detached, and the closed, block or terrace arrangement of houses. A city may generally be divided into several districts, such as (*a*) the manufacturing districts, with factories, industrial establishments, warehouses for wholesale trade, and bonded warehouses; (*b*) the workingmen's districts, comprising laborers' dwellings or cottages, and, in some cities, the tenement-house districts, although it is to be hoped that tenement-houses will ultimately disappear, and that the aggregation of large numbers of people into small, dark, overcrowded and unhealthful apartments will cease; (*c*) the shopping districts, containing the large shops and stores, generally located on the main thoroughfares of traffic, and constituting the retail business section of cities; (*d*) the business section proper, including the centers of wholesale and general business, the exchanges, the banks, the chamber of commerce, the post-office; (*e*) the sections in which the railroad terminals are located, including travellers' headquarters, hotels, express offices, etc.; (*f*) the residential districts, made up by the mansions of the rich and by the dwellings of the well-to-do people.

In laying out the principal thoroughfares on the general plan, we should carefully consider the size, character and the centers of traffic, as well as the radial, diagonal, longitudinal and belt traffic. We should make provision for the traffic on foot, for heavy truck or wagon traffic, for carriage, cab and hack traffic, for equestrians, for stage lines, and tramways, whether propelled by cables, electricity or by horses; finally, we should include the steam railroads and transportation by water, and endeavor to establish some well-considered system in the traffic of a city.

The principal axiom to be followed is that city streets should be laid out not only for traffic, but also with an eye to permanent beauty, by bringing architectural structures and sculptural monuments into agreeable position or into effectual grouping. The requirement that engineering and landscape architecture are to be combined should never be lost sight of in street planning. It is of still greater importance in the laying out of boulevards and of parks, drives and speedways.

The width of streets should be determined according to their importance or the probable amount of traffic. The grade or longitudinal profile, the cross section of the street, its surface drainage, the facility for building, all these matters should be considered.

The rectangular system of streets, so prevalent in American cities, does not merit approval on æsthetic, much less on practical grounds. In a skilfully laid out network of city streets, straight lines of too great length are avoided as being very monotonous and as wearying the eye; gentle curves or variations in the width help. Intersections of thoroughfares should be utilized and set aside for public buildings, such as railroad stations, theatres, churches, museums, banks, telegraph and post offices, court-houses and markets. Schools and hospitals should be relegated to the quieter side streets. Likewise should the street perspectives be beautified by artificial ornaments, monuments, and sculptural works set with a good background, or graceful statues, or by water jets and fountains, or by arcades. On important street crossings and squares there should be

provided landing places affording safety for pedestrians crossing a thoroughfare crowded with vehicles, and these landing places may be adorned with candelabras or with pavilions, with fountains or public seats and benches, or with graceful shrubbery. The intersection of important streets should be utilized for squares, and the artistic embellishment of these should always be considered. Advantage should be taken of the natural configuration of the ground in the laying out of streets. The uneducated eye must be taught to appreciate the beauty of undulating ground, in which opportunity is afforded to look down from the high points on beautiful layouts of commons, on public parks, or to look up from the lower points to buildings or monuments on commanding sites. The beauty of many an imposing architectural structure is, in American cities, lost, owing to the impossibility of looking up to the building.

The division of the cross-section of wide streets into footpath, roadway and boulevard, offers opportunity for landscape effects by providing special promenades in the center, with rows of shade trees or shrubbery and flower-beds, and the traffic may be benefited by separating the carriages, the horseback riders and the heavy teams and trucks.

Regarding the proposed width of streets and the distance between streets or the depth of the blocks, it should be noted that too great width of carriage-way is undesirable, as it tends to increase the dust and dirt, and the cost of street maintenance. Likewise should the distance between streets be limited, for very deep blocks are undesirable and lead, where the land is valuable, to a building up of the interior of blocks with rear dwellings, or with factories, workshops and storage buildings. All buildings should have a frontage on the public street, and the rear part of lots should be utilized for yards; or better, the center of the block may be laid out in well-kept private gardens or pleasure grounds, with low and open dividing lattice fences, or else all the yards in a block may be combined into one large open space, with drying yard, playground and lawn, thus providing plenty of pure air and daylight to the rear

of our dwellings. The ideal mode of building from a sanitary point of view is the detached method, but it is only adapted to the suburbs and outlying villa districts of cities.

Public squares in cities may either serve for general traffic, or for meeting places, for markets, for approaches to prominent buildings, such as city halls, churches, synagogues, theatres, museums of art and of natural history, or schools, or else they are intended for adornment and as locations for monuments. Open squares in cities have a distinct sanitary value, because they afford breathing spaces. If they are laid out as a public garden, common or park, with lawns and flower-beds, shrubs and trees, benches and seats, they afford opportunity for recreation, constitute playgrounds for city children, they promote the healthfulness of a city by lessening the street dust, removing the street noise, and by maintaining a purer atmosphere. Squares and parks are, therefore, aptly termed the "lungs of a great city."

In addition to promenades liberally planted with trees, and open spaces and public gardens, a large city should have public parks and airing grounds, to afford its inhabitants opportunity for taking exercise in the open air. Where possible, the parks should be connected by boulevards, and these, laid out by a clever landscape artist, may afford pretty outlooks on the city, onto the broad expanse of its surroundings, or a distant view of the water.

As regards their location in relation to the plan of the city, all public and important business buildings and structures may be divided into three classes. The first class embraces buildings which are business centers and which *centralize* the traffic, such as city halls, court-houses, exchanges and bourses, banks, main post-offices, houses of parliament, or capitol buildings, judicial buildings, municipal government buildings, halls of record, telegraph and telephone headquarters, hotels, museums, libraries, terminal depots, railroad stations, ferry-houses and docks for arrival and departure of steamships. To the second class of buildings belong those which have a tendency to

distribute traffic, such as sub-stations of post-offices, public telegraph and telephone stations, churches, schools, police stations, open and covered market halls, exhibition buildings, theatres, circus, concert halls, club-houses, other places of amusement, fire-engine houses, people's public baths and wash houses, asylums, livery stables, also buildings in public parks. The third class consists of buildings which should be confined as much as possible to *special outlying sections* of a city, and of these I mention military barracks and military drill grounds, jails and prisons, hospitals, reformatories and orphan asylums, cemeteries and mausoleums, abattoirs and slaughter-houses, cattle and stock-yards, noxious trades, gas works, waterworks pumping stations, reservoirs, standpipes, settling and filtering basins, sewage pump and disposal works, garbage dumps and the like.

In European cities generally much more attention is paid to a good and suitable selection of sites for monumental and public buildings than here. It is unusual to find a church, or a theatre, or a school, located in the middle of a block. Open spaces on at least three sides are required for churches, museums, schools, hospitals and theatres, with the incidental advantage of gaining better light and air and better approaches to the buildings, and of having better and more numerous exits in case of danger from fire or a panic.

The water-fronts of harbor towns or of cities situated on the banks of a river are also worthy of embellishment and improvement. Much remains to be accomplished in American cities in this respect, for here the water-fronts are usually the least attractive portion of a city, whereas in cities of the continent the reverse is often the case. Water-courses or canals flowing through the heart of cities should be kept clean, and may serve to beautify the same, if all liquid or solid filth is carefully excluded, if the banks are rectified and protected, if they are hemmed in by well-built stone embankments, with gardens or parkways, and if picturesque and ornamental bridges are carried over the same. Natural coves or basins may be made points of great attraction, as every one will concede who has ever seen the beautiful Al-

ster-basin in the city of Hamburg, Germany, with its boulevards and garden banks, its hundreds of row-boats, sail-boats, and little steamers on the water, travelling to and fro, and enlivening the landscape.

Some general and sanitary requirements of a well-studied city improvement plan are the following: good location; protection against high water and floods of rivers; dryness and cleanliness of building soil; ample means for traffic, on land and by water; facility for future enlargement; ample public squares, gardens and parks; well-lighted streets and well-laid and well-kept pavements; perfect drainage, sewerage and sewage disposal; easy mode of removal of refuse and destruction of garbage; healthful habitations; freedom from soil contamination; prevention of pollution of rivers, lakes, coves or water-courses; pure drinking water supply and ample supply of water for all other purposes; ample provision for plenty of light and air in the streets, in the centers of house-blocks and in the habitations; avoidance of smoke nuisance, and noiselessness of streets.

The execution of the improvement or enlargement plan for a city requires a large number of well-devised engineering and architectural structures, above as well as below the street surface. For purposes of a water supply a city needs a distributing system of pipe mains, with shut-offs, house taps, street hydrants for fire department use and for washing and sprinkling the gutters and streets, also public drinking fountains, horse-watering troughs, ornamental fountains, etc. For purposes of sewerage the city requires underground pipes and masonry conduits, man-holes, inlets, flush-tanks, house connections, gutters, catch-basins, also public urinals and public water-closet accommodations. Then again, a city requires means and facilities for public street- and house-lighting by either gas or electricity, involving a distributing system of gas pipes, mains, sub-mains and branches, valves and siphon boxes; house and street lamp services, street lamps and candelabras, and, on the other hand, electric wires or cables, subways and electric light poles. For facilitating intercommunication, a city requires telephone and telegraph wires for the public, for the police

and fire departments, with fire alarm boxes, telegraph and telephone stations, and pneumatic conduits for parcels and mail service. Other underground conduits for the distribution of light, heat and power, comprise steam mains, pipes for water, fuel or natural gas, conduits for hot water and for compressed air, electric cables and pipes for distribution of cold refrigeration. On the street surface the traffic requires pavements for carriages and trucks; sidewalks for pedestrians; roads for equestrians; horse, electric and cable roads, with their underground cable and trolley wire conduits—overhead wires should not be countenanced—elevated roads and underground railroads, etc.

The street traffic of a city also requires certain accessories for public information and public convenience, such as house-numbers, street-signs, warning-signs at grade crossings (I may say here that railroad crossings on a level with streets should be abolished in well-laid-out cities), street-clocks, columns for advertising purposes, fire-alarms, signal boxes, columns for weather indications, waiting pavilions for street railways or steamers, public conveniences, lamp-posts, letter-boxes, news stands and pavilions for sale of refreshments, music pavilions, seats and benches, etc. There is no reason why these utilitarian devices should not serve as tasteful embellishments of our streets by having them designed in an artistic manner.

It is finally necessary that a city improvement plan be carried out in accordance with well-framed building and sanitary regulations. Such building regulations refer principally to construction and stability, to safety from fire, to traffic considerations, and to healthfulness of buildings. Those relating to the salubrity of buildings, and to maintenance of the public health, are doubtless of the greatest importance. The rules should limit the size of the area of lots available for building; they should regulate the height of buildings in proportion to the width of the street, to secure light, air and sunshine to the houses. They should control the period when newly-finished dwellings are to be occupied, and should prohibit cellar habitations. Other regulations should have reference to the filling-in material

used for low building lots, to the drainage of low land subject to overflow, to the maintenance of cleanliness on vacant lots in cities, to factories, workshops, stores, and to noxious trades, to schools, places of assembly, like theatres, lecture halls and churches. In order to facilitate building operations, it may be wise to apply building regulations of less severity to the outer districts of a city, or, in other words, to arrange for several distinct building zones.

The engineering works enumerated and described form together a large sanitary system, which must be planned by sanitary engineers to establish safeguards for the public health in centers of population, and which, assisted by a wise sanitary administration, helps to diminish the death-rate of a city.

I had intended to speak to you more fully about matters connected with the general sanitation of towns, some of which I have just been able to scan very briefly, such as the relations of sunlight and sun warmth to health, the avoidance of outdoor and indoor dust, the prevention of the pollution of town air by smoke, vapors and fumes, the planting of trees in wide streets, the laying out of gardens, public squares and city parks and their sanitary benefit to the town dwellers, the means of transportation, storage and sale of the food supply, and other topics, but the time at my disposal does not permit more than the casual reference to these sanitary problems. Nor can I discuss to-night the city graveyards, cemeteries, mausoleums, crematories and other modes of preservation and disposal of the dead, nor the drainage of swamps and malarious districts, the prevention of inundations and storm-floods and of drought, the sanitary influence of forests, the benefits due to forest culture, and the objects of city and village improvement and sanitary associations, all of which will at some time engage the sanitary engineer's attention.

Again, much as I would feel inclined to, I cannot touch to-night upon the sanitary engineer's duties in relation to habitations. The sanitation of the dwelling, the protection of buildings against the elements, the problem of hous-

ing the poor, tenement-house reform, the sanitary features of schoolhouse construction, the proper planning and arrangement of hospitals, of prisons, jails and military barracks, the establishment of people's baths in populous city districts to further bodily cleanliness and health of the working people, the arrangement of markets and of abattoirs, the disposal of dead animals, the construction of mortuaries and city morgues, the fire protection of buildings and of cities, the safety of audiences in theatres and general theatre hygiene—these are all matters pertaining in whole or in part to sanitary engineering.

Industrial hygiene, the sanitation of workshops, the prevention of machinery accidents in manufacturing establishments, the regulation of noxious and offensive trades, the abolishment of public nuisances, the healthfulness of summer hotels and summer resorts, present problems which it is often the business of the sanitary engineer to solve.

The hygiene of the travelling public requires, not only provision of comforts and conveniences, but, above all, of safety and cleanliness. In hotels this means unobstructed fire escapes and fireproof stairs, located, not around, but away from, the elevator shafts, perfect cleanliness of rooms, beds and bedding, bathing facilities, well-kept toilet rooms, safety from sewer gas in sleeping apartments, freedom from coal gas due to stove dampers, avoidance of gas leaks due to defective gas fixtures and the filtering of the water supply, and in particular of the table water.

Public conveyances, in which travellers are often carried for long distances huddled close together, need sanitation as much as our homes. Surface, street and elevated railroad cars should be thoroughly washed, cleaned and aired every night. The ventilation of railroad coaches, of sleeping cars, of railroad tunnels, of ferry boats and of steamship staterooms and berths afford sanitary problems which are not always easy to solve. The luxurious sleeping cars, in particular, could be much improved if more attention were paid to cleanliness and sanitation rather than to decoration and embellishment. Means of ventilating cars are often

absent, or, where they are provided, they are not effective, because they are not rightly handled by the train hands. Among more palpable defects I mention defective lighting, overheating, lack of cleanliness and of ventilation, unclean water tanks, with ice and water of doubtful purity and often mixed together, bad arrangement of car-hoppers, objectionable water-supplied pan-closets in compartment cars of vestibule trains, etc. There is in all cases some danger of the transmission of disease, such as typhoid fever, or consumption by the sputum of invalids. Railway and ship sanitation include much more than this, as you will admit when I recall to you the disgraceful unsanitary condition of many railroad stations, and when I remind you of the crowded steerage quarters on emigrant vessels.

A large part of the practice of a sanitary engineer refers to sanitary inspections, whether examination of houses, or inspection of future building sites for institutions, or sanitary surveys of cities and towns. His acquirements also render him well qualified to assist in drawing up building laws and sanitary ordinances, to see to their proper enforcement in the position of sanitary, or building, or factory inspector, or to prepare in the office sanitary maps, profiles and diagrams of mortality in its relations to meteorological and sanitary conditions.

Another part of his work consists in rendering expert services in cases of litigation pertaining to sanitary works or sanitary patents. To give testimony as an expert witness in court is not always an agreeable duty, particularly under the custom prevalent in the United States, under which experts are engaged by both the plaintiff and the defendant. It is far preferable, to my mind, that experts be retained by the court only, as is the rule in some European countries. I also hold that it were better if experts in sanitary engineering cases were confined to testifying to facts only, and not required to answer hypothetical questions. In any case, they should limit themselves to testimony relating to sanitary engineering questions, and decline to enter into a discussion of problems belonging to sanitary science or the germ theory of disease. Even a well-qualified and learned

sanitary engineer should not offer opinions in court cases as to what may or may not be injurious to health. He should leave this to the medical officers, to the sanitarian, the biologist, and he should confine himself entirely to the constructive side of such works as health officers require for prevention of illness or to increase salubrity. Viewed in this light there is quite a distinction between a sanitary engineer and a sanitarian, which, in cases of litigation, the judge, as well as the attorneys who plead the case, should recognize.

Then again, I must remind you of the special work and duties of the sanitary engineer in case of sudden outbreaks of epidemics, or of sudden calamities or great disasters in civic life, such as earthquakes, river floods, and destructive conflagrations; and of the services which may be rendered by sanitary engineers in time of war, such as the erection of temporary hospitals for the wounded, the housing of soldiers in tents, the maintenance of cleanliness in the camp, the sanitation of battlefields and the prevention of war pestilence.

I trust my audience may have gained a tolerably clear insight into the numerous duties of the new profession; and now, having defined sanitary engineering and gained some knowledge of the education and the practice of the sanitary engineer, and of the problems which engage his attention, we are enabled to answer the question: "Who is not a sanitary engineer?" in the true sense and meaning of the term.

No one should be entitled to the name of "Sanitary Engineer" unless he is amply qualified, by study, special training and practical experience, to offer sound advice in all problems arising in his profession. The mere fact that a man is qualified in a single special branch, for instance, in house drainage or the plumbing work of buildings, should not entitle him to be regarded as a sanitary engineer.

I am quite aware of the fact that, in making this statement, I am stepping on dangerous ground, and that there will be some who may not agree with me. I do not believe in mincing such matters, and I do prefer always to call

things by their right names. Misuse of terms is misleading. A builder or contractor is not an architect, but the architect may, in certain cases, be a builder. A druggist or apothecary is not a doctor, though an educated physician may be, at times, a dispensing chemist. So likewise, a man who does the plumbing work of buildings, or who takes contracts for laying drains or sewers, or who confines himself to repairing or altering defects in house drainage, is not thereby qualified to be considered a sanitary engineer, but a sanitary engineer may, and often does, plan or carry out works of house drainage and interior plumbing arrangements.

A man does not become a physician by the mere act of hanging out a sign, on which he styles himself "M.D.," neither does a man become a sanitary engineer by merely adding these words to his trade sign, when he has obtained a license to run water pipes or to lay sewers, or when he is appointed inspector of nuisances. The innocent public, however, may oftentimes be misled by signs of ambitious tradesmen, such as "Plumber, Gasfitter and Sanitary Engineer," or the still more pretentious sign, "Plumber and Consulting Engineer for Hydraulic and Sanitary Works."

I do not wish, however, to be misunderstood, nor that my words should be misinterpreted or misquoted. Nobody has a higher appreciation of intelligent and skilled mechanics and craftsmen than I, and it is far from me to underestimate the good work done by conscientious men of the trade. But the difference between a trade and a profession cannot be bridged over or eliminated by devices merely calculated to deceive the public. It is just as erroneous to call a man, or to take a man to be, a sanitary engineer, who has had no general engineering training, and whose knowledge and skill is confined to house drainage and plumbing, as it is to think a man cannot be an engineer because he does not build or run engines. And to go a step farther, physicians, when they have made a special study of preventive medicine and sanitary matters, should likewise not be considered sanitary engineers—the term "medical engineer" has even been compounded for the purpose—for they lack the tech-

nical experience and training absolutely required to qualify them for carrying out works of sanitary engineering.

To reiterate: Just as in medicine the eminent specialists must be physicians proficient in general medicine, so in the profession of engineering *the sanitary engineer should be a well-trained civil engineer.*

A few words, in conclusion, in regard to the *general* qualifications of the sanitary engineer. To my mind, he should be a man with the broadest possible general culture. He should not only have a thorough knowledge of his profession, but he should combine with it good business capacity. He should be faithful, conscientious, accurate, honest, trustworthy, sound in judgment and of absolute integrity of character. He should respect his brother engineers in order to win their respect. In order to deserve universal respect, he should, if he has decided to practise for himself, avoid sensational writing or advertising, and confine himself, if he is building up a practice, and is obliged to seek work, to such legitimate advertising as he may accomplish by insertion of a professional card in engineering journals; or by the opportunities which present themselves to him to demonstrate his qualifications and skill in works carried out from his designs or under his superintendence; by original contributions to the technical and engineering press; by the dissemination of essays, or by lectures. Much of the sanitary engineer's work is necessarily of a missionary character, as the public must be educated to appreciate the beneficial effects of sanitation. Not a little of his work requires patience and perseverance. It is, as a rule, up-hill work, until he finally reaps success and the merited reward of a widespread reputation.

Once a reputation is established, the sanitary engineer should be much more closely identified with public matters than has been the case in the past. Among the learned professions engineering occupies the foremost rank, and sanitary engineers in particular, are, by reason of their special training, exceptionally well fitted to be represented in City, State and National Boards of Health, in Boards of

Education and of Charities, in City Councils, city improvement societies and on citizens' committees.

The sooner the fact is recognized in the appointment to municipal offices or boards of public works, that engineering is not politics, the sooner will the reform movement, which has been so happily inaugurated in my own city, spread to other cities and bear good results.

OUR PENNSYLVANIA FORESTS.*

By Dr. J. T. Rothrock,
Secretary of the Pennsylvania Forestry Association.

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

As a nation, our resources have usually been in advance of our needs, or in other words, there never has been a time when our capacity for production has not been in excess of our consumption. When we read of famine in other lands and think that in all our national life no such monster has ever stalked over any considerable portion of our country, we imagine that we are a peculiar people and under a special Divine protection. Anticipating no shortage in the future of any of the necessities of life, we have become reckless in the expenditure of what we have. We have absolutely lost sight of the fact that those who follow may, nay, must inevitably, suffer from our extravagance. Indeed, it is hardly too much to say that most of our legislation is based upon the present and takes almost no account of the future. Hardly a statesman whose name adorns our national records, has fairly looked into the future and shaped a specific policy, to anticipate wants which must press upon us unless we provide in advance for their advent. We have swept the buffalo from the plains, the fish from the streams,

*A lecture delivered before the Franklin Institute, January 4, 1895.

and are, as fast as possible, removing the forests to an extent which older nations have pronounced dangerous.

Before we consummate this last folly it may be well to ask ourselves just what our relations with the trees are. I shall consider this from three standpoints: (1) Forests as holding soil; (2) Forests as making soil; (3) Relation of the forests to the atmosphere; and finally shall draw some general conclusions from the statements previously made.

Forests retain, or hold, soil in its existing position. To illustrate this let me call attention to a hillside in Mifflin County, Pa. When I first knew that ground it was covered with timber. There was not a single gully upon its steep surface; and to this day, upon one end of the same hill, where the timber remains, no sign of wash appears. At present, from one end to the other of the timberless part, the hill is literally seamed and scored by gulches. Its value, as farm land, is absolutely nothing. Nor is this all. The soil, gravel, and even rocks, have been swept like an inundation to overflow and destroy the good soil on the flats below. Thus a two-fold injury has been wrought, one which threatens with each successive year to become worse unless arrested—at a considerable expense to the owner.

Let us take another illustration. Here is a scene in the Valley of Long Run, in Clinton County. The signs of a destructive inundation are everywhere apparent. Huge boulders and massive angular fragments of rocks dot the course of the stream. Fresh landslides show where the retaining soil below has been washed out. If you follow down the course of the stream you will see where the farms have been overflowed, where the original channel has been changed, a new one cut out, and where buildings have been undermined and swept off in the flood, involving a loss of human life which was sickening in its details.

Now return to the head of the stream and what do we find? A principal valley whose steep sides indicate a rapid delivery of water; a number of lateral, smaller valleys, with equally steep sides, and in every one a mountain stream, whose quick flow tells plainly enough with what impetuosity the water is delivered to the main channel.

From almost every part of this valley of Long Run, from even the remotest highlands, whose slopes send their contribution to swell the flood, the surface is as bare as fire and axe can make it; or where the barrenness is not already absolute, the lumberman is at work to complete the naked picture.

Do not misunderstand me. I am waging no war with the lumberman. He has his vocation, and the prosperity of the country demands his product. I am simply considering the facts.

Let us shift the scene, and go over into Rose Valley, in Lycoming County. As I drove through it I was struck by the fact that where the stumps still remained in the fields there were signs of good crops; but when I came to fields which were clear of stumps, and thereby showed that they had been longer under cultivation, generally, the crops appeared to have been smaller. In a word, there was less soil in the old fields than in the newer ones. Then when I came to the foot of the slopes I found what had become of the soil. It was washed out, and the stony surfaces in the older fields showed that it had gone, and explained why the crops were short.

It hardly seems necessary to devote any more space to a discussion of a principle which should be clear enough from the illustrations already given.

Let us now consider the second proposition—*that forests make soil.* First of all, we will note the growth of the mangrove thickets on the coast of Florida. The mangrove is a seaside plant in tropical regions clear around the world. It has its marked peculiarities, and among them is the one that the parent tree holds on to the seed, not only until it is perfectly matured, but until it has well begun its growth. When cast off, the young mangrove is a plantlet, or treelet, about a foot long. Thousands of these are yearly dropped from the older trees on the coast of Florida into the water and carried off by the wind and tide. Perhaps at low tide some of these are stranded on an oyster reef; where the soil is absolutely bare of any sign of what you would consider soil. Nothing but the crevices in a surface which is

covered by the repulsive slime of the ocean exists to offer the young mangrove a foothold. This, however, is sufficient. It is the one plant specially prepared to fill that place, and, once landed, it begins to establish itself and to grow. Nor is this all. No sooner are the roots fairly fastened, and the first trunk two or three feet high, than from the newly formed branches there are sent down hanging "air roots," which attach themselves to the reef as the parent stem had already done. Let us shift the scene and note the vigorous growth of the mangrove on the tropical shores of Jamaica. Near Port Morant one may find forests of this tree possibly seventy feet high. Over the tangled mass of roots one may walk for miles, a foot above the water, without coming in contact with it. This tangle of root and stem is not without its purpose in the general economy of nature. When the tree has attained its growth and fallen, to return by decay to the inorganic condition, it is in the eddies formed by these roots that the matter is retained. By slow degrees, in the course of ages, soil begins to appear above the surface of the water. Slime is buried beneath soil and on the rising earth, forests of a new kind, and possibly of greater utility, may appear.

Or, if we study the bald cypress, a lesson no less impressive is taught. We are quite too apt to think that this tree is specially fitted for bayous and mud-banks and will grow nowhere else. The fact is, the bald cypress is a tree of pliant constitution, well adapted to a wide range of conditions. I have seen it thriving where it grew up out of an asphalt pavement, and also photographed vigorous specimens of it where it stood out in the muddy water of the James River. When we find it in such positions as the one last named, the proper view is that it grows there because it is free from competition by occupying a place in which no other tree of the region will flourish. In the Southern States it forms just such forest masses as the mangrove does in Jamaica, except that it produces no such thickets of "air roots." These trees rise out of the brackish or fresh water, grow, mature, fall, decay, and out of their remains fresh soil is formed to produce dry ground for other crops.

One might be allowed here to call attention to the fact that on the soil formed by the mangrove and the bald cypress some of the most important crops of the world are produced. Indeed, a mangrove thicket strikingly illustrates some of the earlier features of "world-making." Its density, its emergence from the bosom of the ocean, produce an impression which is strikingly at variance with the ordinary course of things in temperate and sub-tropical regions to-day. Furthermore, when we consider the disappearing hemlock forests and recognize the possibilities of modern chemistry, it is hard to estimate what advantages it will place in the hands of the tanning industry, for it contains an enormous percentage of tannin.

No fact of science is better established than that the presence of moisture in the air, over any region, in temperate latitudes, tends to prevent the escape of the earth's heat. Professor Tyndall most forcibly explains that aqueous vapor in the atmosphere of England is as necessary for the vegetable life of that country as clothing is for man. It is equally well attested that plants in a vigorous condition are, during the growing periods, very active in giving off moisture to the air by transpiration, that they even transpire more than is received by the roots, which, of course, indicates another source of supply than the roots. The quantity transpired is very variable for different plants and under different atmospheric conditions; but from known facts, it is well accepted that the volume is enormous. The presence of this enormous body of water in the atmosphere must be accepted, and, if there, its potency must be acknowledged as a factor in climate, if not locally, then generally. It can hardly be doubtful that the change of a country from a wooded to a treeless condition must be accompanied by a change of climate, of moisture in the air, and consequently of temperature.

It appears that in our latitude the result must at least be a climate of greater extremes—extremes which would possibly affect the production of what are now important crops. Strict science has not the whole field to itself, and the observations of intelligent lay observers are at least

worthy of a respectful hearing. Some of these observers, whose remembrance extends back to the time when the country was under more positive woodland conditions, assert, as their opinion, that such changes have already taken place. For example, they assert that the period during which hay may be made has been appreciably reduced during the last half century. Owing to drier atmosphere, they say the grass must be cut at once when ripe, or be damaged as a forage by standing. I neither accept nor deny the statement, but content myself with remarking that the observation is entitled to a hearing, and that it opens the door for a productive line of meteorological research.

From the foregoing it would appear as if the relations between the surface of the country and the forests were most intimate and important. The natural sequence to this conclusion would be the inquiry: What proportion of the State should remain under forest cover? For Pennsylvania, with which we are most concerned, it would be safe to say that forests should be retained wherever they would be the most remunerative crop. This at once divests the subject of all sentiment, and places it under the same common-sense management which we accord to our crops, and it also places forestry where it should be, under agriculture. The mountain axes of the Commonwealth, the steeper ridges, the lowest swamps, where drainage is difficult, worn-out fields, where, owing to steep slopes and natural poverty of soil, it is impossible to retain enough of fertility in the soil to produce remunerative crops of the cereal grains, or even to maintain grass for dairy purposes—all these should be covered again with trees.

To this proposition there would be two natural inquiries. The first, "Is it possible?" The second, "Would it pay?" One may dismiss the first inquiry with the statement that forests may always be produced as a crop when accorded the care of a crop. It seems ridiculous to be obliged to reiterate that in Germany, France, Switzerland, Scandinavia and other European countries, forestry is as firmly established as any other branch of agriculture; but it appears to

be necessary, for to the average American the idea of producing forests is still little less than absurd. The idea is growing; but it will require years to firmly establish it *just where it is most needed.* The remaining inquiry, "Would it pay?" may be answered in two ways: first, does it pay to farm such land as we have indicated should be devoted to growth of forests; second, "Is there any other known way of utilizing these lands, unless they happen to have some mineral deposits?" It will not pay in one year, in five or in ten years: but it will pay, in the longer run, interest and principal on capital invested.

It is well, in this connection, to call attention to the following, which is part of a law now standing on our statute books:

"AN ACT

"For the encouragement of forest culture, and providing penalties for the injury and destruction of forests.

"SECTION 1. Be it enacted, etc., That in consideration of the public benefit to be derived from the planting and cultivation of forest or timber trees, the owner or owners of any land in this Commonwealth planted with forest or timber trees in number not less than 1,200 to the acre, shall, on making due proof thereof, be entitled to receive annually from the commissioners of their respective counties, during the period that the said trees are maintained in sound condition upon the said land, the following sums of money:

"For a period of ten years after the land has been so planted, a sum equal to ninety per centum of all the taxes annually assessed and paid upon the said laid, or so much of the said ninety per centum as shall not exceed the sum of forty-five cents per acre;

"For a second period of ten years, a sum equal to eighty per centum of the said taxes, or so much of the said eighty per centum as shall not exceed the sum of forty cents per acre;

"For a third and final period of ten years, a sum equal to fifty per centum of the said taxes, or so much of the said fifty per centum as shall not exceed the sum of twenty-five cents per acre;

"*Provided*, That it shall be lawful for the owner or owners of the said land, after the same has been so planted for at least ten years, to thin out and reduce the number of trees growing thereon to not less than 600 to the acre, so long as no portion of the said land shall be absolutely cleared of the said trees;

"*And provided also*, That the benefits of this act shall not be extended to nurserymen or others growing trees for sale for future planting.

"SEC. 2. The owner or owners of forest or timber land in this Commonwealth, which has been cleared of merchantable timber, who shall, within one year after the said land has been so cleared, have given notice to the commissioners of their respective counties that the said land is to be maintained in timber, and who shall maintain upon the said land young forest or timber trees in sound condition, in number at least 1,200 to the acre, shall, on making due proof thereof, be entitled to receive annually from the commissioners of their respective counties the sums of money mentioned in the first section of this act. *Provided*, That the first period of ten years shall be counted from the time that the said land has been cleared of merchantable timber, and that after the said first period of ten years, the number of trees upon the said land may be reduced as in the said first section is provided."

It is a striking example of the folly of men that they will pay taxes on unproductive land, maintain fences, and bestow their labor upon it, render it each year more and more impoverished and continue to do this in spite of the fact that it will yield them nothing in the end. This folly is the more striking when it has been shown, all over the State, that such a law as the above exists for the sole purpose of ameliorating the condition of those "small land owners" who need it most. But how shall one characterise the stupidity of a farmer who owns a few acres of half-grown oak on a barren, steep, hillside, with a slaty surface and a northern exposure, and who cuts it off to sell in a market which is on the very lowest round?

It is an old, threadbare argument, that substitutes for

wood will be found. The statement is doubtless true, and might have some weight were it not for the fact that new uses are also being found for it much more rapidly than the substitutes for it are. The plain undeniable fact is, that wood will always remain almost as much an article of prime necessity as water.

There is another aspect of the problem which may well be considered: rates of interest tend to become lower as countries become better settled and business reaches a condition approaching an equilibrium. Contrast, for example, the interest on capital invested in England, and in Oregon and Washington. The 8 per cent. almost invariably comes from the lands to the west of us, and the undoubted tendency is for good securities to command lower rates. There is an evident exception to this general rule. Our population is becoming more dense, our timber-land areas are becoming more and more depleted, until it requires no prophetic eye to see the practical obliteration of important lines of business in this Commonwealth. In other words, the demand is continually increasing, and the supply as certainly decreasing. The inevitable tendency must be to increase the value of standing timber.

Thus far no allusion has been made to the spontaneous restoration of our forests. It is probably safe to say that in no temperate region is this tendency more marked. I might even go further, and say that the quantity of wood which an acre will produce spontaneously each year is a perpetual marvel to the European forester. It seems to be equally a marvel to our own people that when once a forest is removed it is not succeeded promptly by another of the same kind. As a matter of fact, there is no more reason to expect a perpetual succession of the same kind of timber than there is to expect that, from a single sowing, men should reap a perpetual succession of the same kind of grain; and there is no more reason why the existing tendency should be used, as it often is, as an argument against tree planting than there is why it should be used as an argument against grain sowing. The very same methods which ensure the crop we desire in the one case, will ensure

it in the other, the chief difference being the time of maturing. It is vastly important that the widespread error in regard to our most important tree, or what was our most important tree, the white pine, should be corrected. There is no species in which the tendency to restoration by seed is more marked. Over the State, here and there, in numberless places, one may see thriving groves of this tree coming on; nor does there seem to be any acceptable reason why the coming crop should not be as good as the first, if sufficient time be allowed for the wood to fully mature. It is well known to experts that the white pine does not select the richest soil for its favorite place of growth. This only makes it the more valuable. The one great foe to the young white pine is the unrestrained forest fires. It seems to be a wretched public policy which permits land to lie for half a century unproductive after its white pine crop had been removed. What shall be said of the policy which declines even to protect the spontaneous bounty which nature offers, but allows fires, year after year, to destroy the coming timber crop?

I do not draw upon my imagination when I propose this question, but at this moment can point out extensive areas in this State, which are now a picture of desolation, but which, under a wise State policy, should have been on the verge of reaping a harvest worth millions of dollars for its second growth of timber. One of the shortcomings which will be hard for the next generation to excuse, will be that we have stolidly ignored their interests, so far as protection of our timber resources are concerned. Yet it must not be forgotten that the present generation is the first one, of civilised men, born on American soil, to whom a possible scarcity of timber, or an unfortunate train of circumstances growing out of that scarcity, has presented itself as a present pressing problem. To those who preceded us, the problem was what to do with the excess. Scarcity faces us, however, squarely.

We recognize clearly enough two aspects of forestry—individual and State forestry. Let us briefly consider each.

State forestry may be said to concern itself with tree restoration and removal on soil which belongs to the State, or on soil which it is for the general interest that the State should control. Properly conducted, State forestry should consider ultimate consequences, and shape a perpetual policy which should extend forward indefinitely. It considers measures in the light of State perpetuity. It raises and solves the question as to what will be the ultimate effect on the proper conservation of water in the soil. How will stream beds be affected if this or that body of timber is destroyed, and what kind of timber can be grown most advantageously to the Commonwealth on any given area? Individual interests are, by it, wholly submerged in the general consideration: what will longest preserve and most benefit the community?

Of course, it is an open secret that State forestry has hitherto flourished most under the protection of a monarchical government. Perhaps it always will. With the recurring cries of "turn the rascals out," marking the change from one administration to another, it would be folly to expect a permanent policy, which could calmly contemplate any plan looking into the next century for its completion, however worthy that plan might be. The temptation to meddlesome interference is too great to be successfully resisted.

It follows, then, that the next best plan must be substituted for a general system of State forestry, and the latter appealed to only when it must be.

We believe that the highest function of the State is to allow every man the fullest chance to work out the best that is in him. Greater help than this becomes a doting paternalism, and is more likely to weaken than to strengthen the recipient. Now, to apply this principle, what is required? First, that each person should know how to act. Our public school system has this idea for its basis. It is more a public than a private benefit that we should know how to stamp out contagious disease, or to utilize present resources so as not to entail want upon the children we have begotten. In rational treatment of our forests, as a people, we are wholly

ignorant, and this public admission for the mass of the people is good for the national soul. But we are not hopelessly stupid. On the contrary, no people pick up a new idea with greater avidity, or comprehend it more promptly, if the moving motive is properly appealed to. To convey this instruction the State should own forest reservations where approved methods of tree culture could be illustrated, and where, at the same time, the State could have under its own absolute control such areas, as, if allowed to remain the property of the individual, would become a menace to the peace and prosperity of the community, by the frequent unrestricted deluges which would pour down from the steep and naked slopes. Ignorance of forestry to-day will cost this Commonwealth not less than $37,000,000 annually, in the near future, and will leave us with a great gap in the list of our most productive industries.

Furthermore, individual forestry should be encouraged, because the surface of the State must, to a certain extent, be covered with trees. The interest of the people demands their *presence*, as well as their *products*. It is merely a question whether the State shall, at a great cost, imperfectly preserve this equilibrium, or make it the interest of the individual to accomplish the same result for it, not only cheaper, but better. We may lay down the general proposition that a tree pays the State, in instant benefit, for the privilege of growing, every hour that it stands. Yet with this incontestable truth in plain view, our laws are actually placing a premium upon a system of forest destruction, which is as unnecessary as it is wasteful. As things now are, there is practically a prohibitory tax upon maintaining tracts of timber, which the future will need vastly more than we do. Or to put the facts in another shape, we may say that there are vast areas of woodland in this State which, in the last thirty years, have been confiscated by taxes, because these have aggregated more than the land can be sold for to-day. To make matters worse, during all this time, in spite of taxes being paid, the owner has received for the same property no protection whatever. The very same county commissioners who expend his money

refuse to accord the protection against forest fires which the law makes it their specific duty to furnish.

The time will come, and can come none too quickly, when not only will this gross injustice be abated, but when the true relation of the forests will be so plainly recognized that the individual will find the State encouragement which he needs to enable him to serve himself in serving the community.

INTERSTITIAL SPACE.

By T. Dunkin Paret.

London *Engineering*, for February 22, 1895, contains an abstract of a paper by Mr. Spencer R. Newberry read before the Ohio State Engineers' Society. This paper refers to the manufacturing of concrete. The abstract begins by stating that "it is well known that the voids in a mass of particles, all of nearly uniform size, are greater than when the dimensions of the particles vary largely, and hence in cement testing, the voids in standard sand, carefully ground to be uniform as possible, are much greater than in ordinary gravel." The abstract then states that "in making a concrete the materials should be mixed so as to fill the voids as full as possible, the amount of cement required for this being increased by ten to fifteen per cent. for safety." It also says "that a suitable addition of gravel to sand may strengthen the concrete," and gives a tabulation showing various proportions of cement, sand and gravel, with the crushing strength in pounds per square inch duly tabulated.

While this abstract may do injustice to Mr. Newberry's paper, its general effect is that produced by nearly all formulæ for the manufacture of concrete and by all articles in reference to such manufacture. In other words, there are certain facts and figures given, which are definite and specific, and a general vagueness in reference to that secret of quality which really lies (the cement being assumed as

always of equal quality) in *the proportioning of the filling to the interstitial space.*

If an absolute rule could be discovered by which proper proportions could, in all cases, be arrived at, such a rule ought to be of inestimable value, not alone in its relation to the manufacture of concrete, but also in reference to the proportioning of very many mixtures. Certain facts leading to the establishment of such a rule are to be found in a series of investigations concerning the manufacture of solid emery wheels, which investigations had their origin in a rather peculiar manner.

In an attempt to establish the varying qualities of different kinds of emery by the manufacture of these kinds into solid wheels, and by subsequent scientific tests, certain startling discrepancies were discovered. A number of wheels made by exactly the same formula were found to differ greatly, and various facts indicated at once and unquestionably that the difference was not due to the intrinsic quality of the emery. The question was then carefully considered as to how exactness of formula could be arrived at; for it is evident that, in a mineral like emery, amounts of equal quantity by weight might differ considerably in volume. Further investigation made that fact apparent, which, indeed, seems evident on theory, that, in order that the mixture should be of the same formula, exact bulks ought to be taken, rather than exact weights. Wheels being made of different emery by the same formula, equal bulks of emery being taken, differences in quality were again discovered, clearly not due to the difference in the quality of the ore. The suspicion then arose that this difference was due to the amount of interstitial space, the theory being that there was more space in some cases than in others, and that, where there was less space, there was an excess of that material which was used to bind and fill. To settle this fact, a prolonged series of experiments was made, whose course was as follows: An accurately fitted cubic inch cell of planed cast iron was made, and this cell filled with emery. Three trials were made with each kind of emery. At each filling of the cell an equal number of taps was given with a mallet upon

a wooden rammer, and the cubic inch mass was carefully levelled at the top. A medicine dropper, after having been tested as to its uniformity of drop, was employed to fill the interstices between the emery with water. Three trials were made in each case, and it was at once discovered that while one brand of emery only required 136 drops to fill it, another kind required 152. As doubt might still exist as to whether the absorptive capacity depended entirely on the interstitial space or upon some possible porousness of the mineral (although emery is supposed to be practically impervious to water) the attempt was made to demonstrate whether the variation was due to porous absorption or to the variation of interstitial space. This was settled by taking grains of that quality which only took up 136 drops, and so treating them that the angular corners were worn off and the grains rounded. It was then found that they took up 155 drops.

In these facts there is nothing startling or new, it being well known that a mass of perfect spheres of one diameter would have more interstitial space than a mass of atoms of irregular sizes and shapes, whose flattened sides and angular points would so arrange themselves under pressure as to come in the closest contact and leave the least amount of interstitial space. But, while there is nothing new in the general result, it may be that no exact data are to be found of the same character as those now offered, and from which deductions can so safely be made. We furnish herewith a tabulation showing the numbers of minims of water required to fill the interstices in one cubic inch of emery, giving the weight of the cubic inch in each case, and the percentage by weight of water required to fill the interstices.

Name of Emery.	Number of Emery.	Minims of Water Required to Fill Interstices in 1 Cubic Inch Emery.	Weight of 1 Cubic Inch of Emery in Grains.	Per Cent. of Water by Weight Required to Fill Interstices in 1 Cubic Inch Emery.
Tanite Mills Emery	6 U C	131	545	14·05
" "	10	133	542	14·30
" "	14	137	539	14·75
" "	18	139	533	14·99
" "	24	140	530	15·20
" "	36	140	526	15·32
" "	54	141	522	15·51
" "	80	147	522	16·07
" "	100	153	512	16·88
" "	140	160	504	17·80
" "	180	164	502	18·17
" "	200	164	502	18·17
" "	Ex. R. F.	180	427	22·27
Average		148	516	16·32
Equal parts by weight of the above thirteen sizes		95	675	8·73
Tanite Mills Emery	20 U C	136	532	14·64
Wellington Mills Emery	20	149	531	16·02
Washington Mills Emery	20	152	529	16·34
Tanite Mills Emery	20 U C R	155	532	16·53

The emery used in above tabulation is numbered to correspond with the mesh of the wire cloth on which it was made; but as commercial emery answering to these numbers varies considerably in size, all of that which was used in these experiments was carefully sifted by hand on the same sieves.

The regularity of the progression in each series of numbers is remarkable from the fact that the experiments were not made in consecutive order, as tabulated, but the different numbers were taken entirely at random at different times covering several weeks. Three trials were made with each number of emery, the mould being first filled half full of emery, and then receiving ten light blows upon a wooden plunger, then filled level and receiving ten more light blows, then filled heaping and receiving five blows, then finally levelled and filled with water from the dropper. *The facts indicate clearly that the interstitial space does not depend entirely upon uniformity of size, but is governed largely by diversity of shape.*

The tabulation given in *Engineering*, and those generally given in reference to the manufacture of concrete, which

roughly state so many parts of cement, so many parts of sand, and so many of gravel, seem to us vague in the extreme; and it would appear that a process, analogous to that used in arriving at the interstitial space of emery, might be used easily, cheaply, practically, and with great effect, in the manufacture of concretes and other mixtures. Where concretes are made in quantity, stone crushers and sifting machines are commonly used. It would be an easy thing in every such case to have a cubic foot cell in which crushed stone (of the average size actually being produced by the stone crusher and sifter then in use), was filled, and the interstitial space of that very stone arrived at by the use of water or other fluid. In like manner both sand and gravel could be so sifted that the average size of each was ascertained, and the sand be used as a partial filler for the interstitial space of the gravel. While the crushing strength of concrete is no doubt largely affected by the cleanness, roughness and angularity of the freshly-crushed stone surfaces, and by the areas of the lime and silica which come in contact, it, nevertheless, seems evident that the crushing strength would be greatly modified by the amount of filling between the stone being so carefully proportioned to the interstitial space that, when that coarse stone was compressed to its utmost extent, the irregular space would be completely filled, while the faces of the stone which came nearest in contact had only a slight layer of filling between them.

In the subjoined table will be found a few facts concerning the interstitial space in crushed stone. To obtain the result shown in this brief tabulation, a rectangular box with a capacity of one cubic foot was used, which box was filled as nearly level as possible with stone and then weighed, the interstices filled with water, and the whole weighed the second time.

NAME OF MATERIAL.	Approximate Size in Inches.	Weight of 1 Cubic Foot of the Material.	Water Required to Fill Interstices Contained in 1 Cubic Foot of Matrial, Pounds.	Per Cent. of Water by Weight Required to Fill Interstices Contained in 1 Cubic Foot of Material.
Broken Ore (Emery)	3½ × 3½ × 2¼	126	29¼	18·83
" "	3½ × 2¼ × 1¼	116	32¼	21·75
" "	2 × 1¼ × ¾	121¼	31	20·36
Rounded Stone (from creek)	2¼ × 1½ × 2¾	95	27	22·13

On theory, it might have been imagined that the rounded stone would, as has been suggested for exact spheres, contain more interstitial space than the crushed ore, but the crushed material was so irregular that it formed bridges, and, unlike the fine emery grain and unlike the stone pounded down in cement and sand, it could not bed itself or become more compact, but remained in the loose position in which it was thrown. The facts which appear most striking in these investigations are a very regular increase of space and diminution in weight of emery grain, as this latter increases in fineness—and the increase of 12·91 per cent. of space due to the mere change of shape in the Tanite Mills emery marked respectively UC and UCR, and the very remarkable decrease in space and increase in weight where thirteen sizes were combined in one cubic inch. The facts here given are not presented as affording an adequate explanation of how a perfect cement can be made, but are rather intended to suggest to other investigators practically interested in the subject a method by which exact results can easily and cheaply be secured.

THE FRANKLIN INSTITUTE.

Stated Meeting of May 15, 1895.

MR. H. R. HEYL, Vice-President, in the Chair.

[The Chairman announced the paper of the evening, and introduced the speaker.]

THE BALL NOZZLE.

BY ARTHUR KITSON.

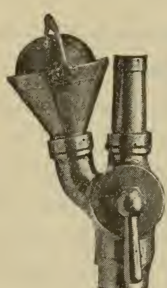
Among the multitude of inventions which, year by year, find their way to the patent office, none attract more attention than those inventions which appear to be of the nature of a paradox, and which the newspapers are fond of describing as "scientific puzzles."

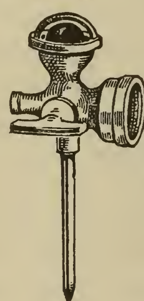
Such inventions as the injector, by means of which water is forced into a steam boiler by the same pressure of steam as that contained in the boiler itself; the down-draft furnace, in which the air for combustion is supplied at the top of the fire instead of at the bottom; the system of heating rooms, by placing the hot-water pipes on the ceiling instead of on the floor—all such inventions which operate on the reverse plan to that with which we are accustomed, at first sight strike us as contrary to the natural order of things, and there is a tendency amongst a certain class to consider the phenomena as marvelous.

Of the very recent inventions that have in this way excited a great deal of discussion, what is known as the "ball nozzle" is probably the most widely advertised, and the principle governing it the least understood. Because in its operation it presents a phenomenon hitherto unobserved, it has been characterised by the press as contrary to the laws of science. There is, however, nothing of the miraculous or of the supernatural which cannot be explained by well-known scientific principles.

The "ball nozzle" is one of the simplest inventions ever designed. It consists merely of two parts: a bell-shaped or flaring-mouth nozzle, and a ball. The nozzle is connected

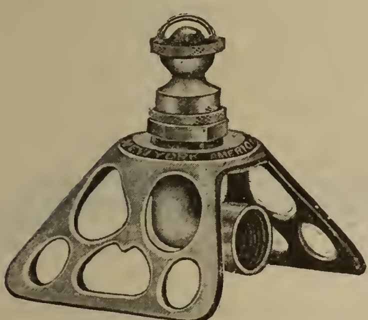
to a water or air supply, and the ball is placed loosely in the mouth of the nozzle. The ball steadfastly adheres to the nozzle and refuses to leave it, notwithstanding the great pressure of the issuing stream of air or water, and no matter what may be the position of the nozzle, whether vertical or horizontal, or whether the nozzle be turned directly towards the ground. As soon as the pressure is released and the supply of water ceases, the ball, obeying the law of gravity, falls. Variations of pressure from a few ounces to hundreds of pounds to the square inch fail to change the nature of the seeming paradox. In the case of water, the effect of the ball is to divide what would otherwise be a straight stream into a thin, fan-shaped spray, which spreads itself in a circle all around the nozzle. It is in this respect that its

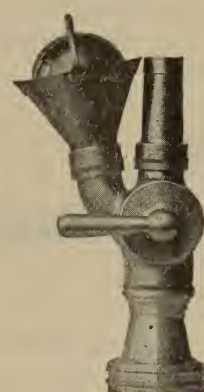




utility arises. One of the essentials of a good water spray for agricultural purposes, or for lawn sprinkling, is the equal distribution of the water, so that an even supply can be furnished without much expenditure of energy. In this field the ball nozzle furnishes an almost perfect machine and seems to be the only genuine "rain-maker" now placed upon the market. With a pressure of 80 pounds to the square inch and a $\frac{3}{16}$ orifice, it is possible to distribute a water supply over a circular area 60 feet in diameter. Such a machine is a convenience and a labor-saving invention which only those who have been accustomed to the old-fashioned lawn-sprinklers can properly appreciate. As a method of distributing fresh air to railway cars or rooms, this invention also seems to fill an important function. But

its most useful field, and one in which it comes as a blessing to humanity, is that of a fire extinguisher. It is one of the glories of science and of invention that, whilst the progress of the human mind in the realm of discovery often brings increased danger to human life, accompanying it—like a guardian angel—are those inventions which act as safeguards to protect life from those dangers to which inventions have given rise. With the ever-increasing dangers which increased speed of ocean travel has occasioned there have likewise arisen increased means and facilities for saving life. The danger attending the use of elevators brought forth the safety catch; and rapid transit, furnished by the trolley system, is soon to be accompanied with the fender,

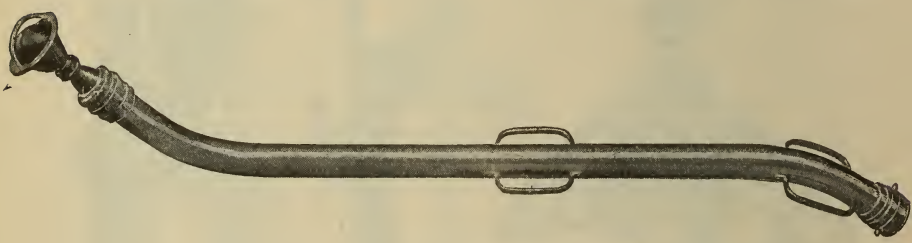




which will make it almost impossible to sacrifice life in the accomplishment of so desirable an object.

Fire is at once man's preserver and his destroyer, and few things indispensable to him have proved so destructive of life and property as this element. It is estimated that, during the past twenty years, not less than 250,000 lives have been lost, and over $200,000,000 of property destroyed by fire in this country alone. An invention that will in any way mitigate or lessen this awful destruction of life and property must be hailed as one of the greatest benefits that the mind can confer upon society. It is in this field that the ball nozzle will serve its highest function. The large nozzles displayed here to-night are designed for this particular pur-

pose. You will see the end of the fire nozzle has two openings—one consisting of a straight orifice, from which a solid thick stream may be directed, as in the ordinary fire nozzle, and the other consisting of the ball nozzle. A three-way valve serves to direct the water to either of the openings. The *modus operandi* is as follows: A fireman, on reaching a building in which a fire is raging, first directs the straight stream against a window of the building in order to reach the fire with the spray. He then turns his valve and admits the water to the ball nozzle and directs it toward the fire. On entering the building he can proceed at once to meet the fire by placing the nozzle in front of him. He then becomes enveloped with a sheet of water, the force of which is sufficient to drive before him the smoke, at the same time extinguishing the flame. It is impossible for the



smoke to penetrate through the solid sheet of water in front of him. He is thus able to avoid suffocation, on the one hand, and death by fire on the other.

Those who have witnessed large fires and have studied the action of the ordinary fireman's hose, must have been surprised with the apparently slight effect which the water has had upon the fire. The reason is that the whole stream and force of water is directed upon a very small space, not many times larger than the orifice through which the water escapes. To overcome this defect it becomes necessary for the fireman to keep the nozzle moving so as to distribute the water. The result, however, is not satisfactory. Certain parts of the fire get more water than is sufficient to extinguish the flame, and other portions do not get any. Moreover, whilst the water is directed on one small area, the fire is making headway in other portions of the build-

ing. It must have occurred to many a man, especially firemen, that if the force could be immediately distributed from one source of supply, sufficient to cover the whole or a large part of a building, that fires could be much more rapidly extinguished and with less danger and loss. This is precisely what the ball nozzle does. Instead of concentrating large volumes of water upon a small area, the nozzle distributes it evenly over large areas, so that all parts of a room or side of a building can be treated equally to the fire-extinguishing element. It is estimated that fifty per cent. of the damage and loss occasioned from fires arises from the excessive use of water. This must be so from the ordinary fire apparatus, and it generally happens that what the water saves from the fire's ravages, is destroyed by the water itself. This evil the ball nozzle must naturally overcome to a large extent. It requires less water to extinguish a fire than by any other system, owing to its equal distribution. Another very important feature is the fact that one fireman can handle a hose with the ball nozzle, where ordinarily it requires three or four men. This seems to be the result of the distribution of the water from the nozzle and the manner in which it comes in contact with the air. A straight stream causes a certain recoil of the hose and necessitates the employment of several men to each hose. Frequent tests of the ball nozzle show that this recoil is much less than in any other, and can be successfully resisted by one man.

In this respect its utility is found to be most valuable.

I refer you to the circulars that have been placed in this hall, containing the endorsement of the various insurance companies and underwriters throughout this country. No institutions are more particular or more conservative about endorsing fire-extinguishing devices than insurance companies, and yet to none are such devices of more importance. Not less than 130 of these companies have endorsed this invention as an improved fire appliance. Judging from the numerous accidents that have occurred recently in private houses from defective flues and exploding lamps, it appears essential that some appliance for extinguishing

fire should be provided in every home, and it seems to me that by the aid of this invention the problem may be solved. From twenty-five to fifty feet of hose, attached at one end to the water supply, and fitted at the other with a ball nozzle, may be placed in every bath-room and kitchen, and, in the majority of cases, would serve to extinguish fires in private houses before much damage had occurred.

I have briefly described this invention and its most useful applications and have left the explanation of the phenomenon for final discussion. The problem connected with this invention may be put thus: Why does the ball adhere to the nozzle when there is behind it a force aggregating as high as hundreds of pounds pressure? The explanation usually given is that the atmospheric pressure holds the ball in its place and prevents it from falling or leaving the mouth of the nozzle. To this others answer that the pressure behind the ball far exceeds the atmospheric pressure; for instance, there is an exhibition given daily in New York with one of these nozzles where the water pressure equals 100 pounds per square inch, and as the atmospheric pressure is only about fifteen pounds, it would at first sight seem that the excess of pressure on the under side of the ball was eighty-five pounds, and ought, therefore, to expel the ball. The error, however; in this argument arises from failure to distinguish between the pressure of the water when confined in the pipes and when issuing around the ball. It is very certain that if 100 pounds pressure were acting directly upon the ball, it would be blown out of the nozzle, but it does not appear to me to act in this way. When the ball is confined to the mouth of the nozzle and pressed against it, it is undoubtedly subjected to the pressure of the water, but the moment it is raised slightly from the mouth, it is no longer subjected to this pressure, since the water is escaping all around it. In this respect it resembles the lid of a tea kettle when the water is boiling. By plugging the spout, the lid will be raised by the steam pressure sufficiently to allow the steam to escape at the sides. The explanation that seems to me

to be the correct one is as follows: The ball is acted upon by three forces: first, gravity; second, atmospheric pressure; and third, the force of the issuing stream. At first, the atmospheric pressure is the same at all points, and hence gravity has free play; but as soon as the stream passes through the nozzle, the atmospheric pressure from the under side is counteracted by the momentum of the issuing water, and the ball rising to a point where the water can pass freely around the sides, without pressing materially upon the ball, we have the full pressure of the atmosphere on the under half-side of the ball resisting the force of gravity. The ball, therefore, simply serves as a deflector to divert the current of water or to spread it out, and the resistance of the atmosphere against the ball suffices not only to perform this operation but also to sustain its weight.

It is possible that the density of the air may also be somewhat increased under the ball by the action of the spray. With a heavy pressure, the ball is further removed from the nozzle than with a light pressure. The same holds good respecting a heavy ball and a light ball. Most of these so-called paradoxes may be attributed to momentum or inertia. Take, for instance, the phenomenon of the injector. "If a 1-inch opening in a boiler, carrying 15 pounds pressure above the atmosphere, be made, if there is no reduction by friction, steam will issue from it at a velocity of about 1,440 feet per second, and the steam which would issue from it would be 10 cubic feet per second, which would weigh $\frac{2}{3}$ of a pound. When this steam is condensed to water, it maintains its velocity but is reduced in volume from 10 cubic feet to $\frac{1}{90}$ of a foot, or in other words, the stream of steam of 1-inch area, which issued at 1,440 feet per second, is reduced to a stream of water $\frac{1}{32}$ of an inch in diameter, having the same velocity—1,440 feet per second.

"The laws of hydraulics show that water will issue from a vessel under a pressure of fifteen pounds per square inch, with a velocity of forty-five feet per second, and that any stream having a greater velocity than forty-five feet per second, if directed against the orifice in the vessel, will enter it, notwithstanding the pressure inside the vessel.

The jet of condensed steam has a velocity of 1,440 feet per second, or more than thirty times that necessary to re-enter the boiler. This velocity is, therefore, reduced by mixing it with 900 times its weight in water, and this mixture will still enter the boiler."* This, of course, is merely theoretical and is largely reduced by friction; but in practice it is well known that steam will carry many times its own weight in water into a boiler from whence the steam is itself derived. We have, therefore, in the ball nozzle, the momentum of the moving stream of water which overcomes the atmospheric pressure on the under side of the ball, and the inertia of the ball which serves to keep it from moving, aided by the atmospheric pressure on its top side. This is my own explanation of a phenomenon which seems to puzzle a great many people, but which is strictly soluble by the well-known laws of physics.

In conclusion, I believe this invention, simple as it is, is destined to become a very great friend of society, particularly as a protection against the scourge and devastation of fire, and a means of saving human lives as well as very much of the wealth which annually disappears in smoke.

HAVING THE LOGARITHMS OF TWO NUMBERS, TO FIND THE LOGARITHM OF THEIR SUM OR DIFFERENCE.

By Nathaniel Hill.

For the solution of this problem, *addition* and *subtraction* logarithms were devised; Zech's seven-figure tables being published in the year 1849, and the five-figure tables of Gauss presumably quite as early, as his name is often used to identify this kind of logarithm. Newcomb's five-figure tables, Pierce's, Wheeler's and Macfarlane's four-figure tables are more recent, and are also American publications.

* Appleton's Cyclopædia.

Newcomb aptly says of these tables: "The problem can, of course, be solved by finding the numbers corresponding to the logarithms, adding or subtracting them, and taking out the logarithm of their sum or difference. The table under consideration enables the result to be obtained by an abbreviated process."

It is proposed here to show methods of solving the problem without other than the common logarithmic tables, which will compare favorably with the method by special tables, in respect of abbreviation, convenience and precision.

The use of seven-figure tables will first be explained: Take the difference of two given logarithms as the argument, and when this argument is 6· +, 5· +, or 4· +, take, respectively, the $\frac{1}{100}$ part, the $\frac{1}{10}$ part, or the whole tabled difference belonging to the tabled logarithm nearest to the argument, which add to the larger given logarithm for the logarithm of the sum, or subtract the same for the logarithm of the difference.

When the argument is 3·+, or 2·+, and the logarithm of the sum is required, take the difference between the tabled logarithm nearest to argument, and that logarithm, one line or ten lines below, and add to larger given logarithm; for the logarithm of the difference, take the difference between the nearest tabled logarithm and that, respectively, one line or ten lines above, and subtract from the larger given logarithm.

The principle involved cannot be applied to the remaining cases; that is, when argument is 1·+, or 0·+. The method applicable to these cases will be explained after the above *special method* is exemplified.

EXAMPLES.

1st Argument = (diff. (1) and (2).) . .	(3)	6·2439554
Given	(1)	7·8798411
"	(2)	1·6358857
Tabled diff., 248·	(4)	2
Add (4) and (1)	(5)	7·8798413 = *log. of sum.*
Sub. (4) from (1)	(5)	7·8798409 = *log. of diff.*

2d Argument = (diff. (1) and (2).)	(3)	5·2439554
Given	(1)	6·8798411
"	(2)	1·6358857
Tabled diff., 248·	(4)	25
Add (4) and (1)	(5)	6·8798436 = *log. of sum.*
Sub. (4) from (1)	(5)	6·8798386 = *log. of diff.*

3d Argument	(3)	4·2439554
Given	(1)	5·8798411
"	(2)	1·6358857
Tabled diff.	(4)	248
Add (4) and (1)	(5)	5·8798659 = *log. of sum.*
Sub. (4) from (1)	(5)	5·8798163 = *log. of diff.*

4th Argument	(3)	3·2439554	Nearest tabled log.	·2439553
Given	(1)	4·8798411	Log. on line below	·2442029
"	(2)	1·6358857	Diff. (4)	2476
	(4)	2476		
Add (4) and (1)	(5)	4·8800887 = *log. of sum.*		
	(1)	4·8798411	Log. nearest arg.	·2439553
	(4)	2477	Log. on line above	·2437076
			Diff. (4)	2477
Sub. (4) from (1)	(5)	4·8795934 = *log. of diff.*		

5th Argument	(3)	2·2439554	Nearest tabled log.	·2439553
Given	(1)	3·8798411	Log. 10 lines below	·2464247
"	(2)	1·6358857	Diff. (4)	24694
	(4)	24694		
Add (4) and (1)	(5)	3·8823105 = *log. of sum.*		
	(1)	3·8798411	Log. nearest arg.	·2439553
			Log. 10 lines above	·2414718
	(4)	24835	Diff. (4)	24835
		3·8773576 = *log. of diff.*		

A general method, applicable to all cases in all tables of logarithms, not as convenient, however, as that shown for the cases already given, now follows, and is to be used for arguments 1· + and 0· +, and sometimes, for argument 2· +.

Enter table with the difference of the given logarithms, and observe the number corresponding to argument, and, for the logarithm of the sum, take out the logarithm of a number one unit larger and add to the smaller given logarithm ; for the logarithm of the difference, take out the

logarithm of a number one unit smaller and add to the smaller given logarithm.

6th Argument	(3)	2·2439554 = log.		175·37004
Given	(1)	3·8798411	Add . .	1
"	(2)	1·6358857		
Log. 176·37004	(4)	2·2464248		176·37004
Add (4) and (2)	(5)	3·8823105 = *log. of sum.*		
				175·37004
			Sub. . . .	1
				174·37004
	(2)	1·6358857		
Log. 174·37004	(4)	2·2414719		
Add (4) and (2)	(5)	3·8773576 = *log. of diff.*		
7th Argument	(3)	1·2439554 = log.		17·537004
Given	(1)	2·8798411	Add . . .	1
"	(2)	1·6358857		
Log. 18·537004	(4)	1·2680395		18·537004
Add (4) and (2)	(5)	2·9039252 = *log. of sum.*		
	(2)	1·6358857		
Log. 16·537004	(4)	1·2184568		
Add (4) and (2)	(5)	2·8543425 = *log. of diff.*		
8th Argument	(3)	·2439554 = log.		1·7537004
Given	(1)	1·8798411		
"	(2)	1·6358857		
Log. 2·7537004	(4)	·4399167		
	(5)	2·0758024 = *log. of sum.*		

It may be noted of the above cases that the second reference is conveniently made from the first; that is to say,

with argument	0· +,	at same place on	page	10, leaves	forward or back.
"	1· +,	"	"	1 leaf	" "
"	2· +,	"	column	10 lines	" "
"	3· +,	"	"	1 line	" "
"	4· +, at adjoining logarithms.				
"	5· +, and above, to same logarithm and proportional parts.				

Two cases showing irregularity in the second reference are shown below:

Argument ·302—, and logarithm of difference required:

9th Argument	(3)	·2439554 = log.		1·7537004
	(1)	1·8798411	Sub. . . .	1
	(2)	1·6358857		·7537004
Log. ·7537004	(4)	9·8871957		
		1·5130844 = *log. of diff.*		

Argument more than ·954, and logarithm of sum required.

10th Argument	(3)	·9639554 = log.		9·20355
	(1)	1·8798411	Add . .	1
	(2)	·9158857		10·20355
Log. 10·20355	(4)	1·0087512		
	(5)	1·9246369 = *log. of sum.*		

The methods shown for arguments 2·+, and larger, apply to five, and four-figure tables, in the order following:

Seven-figure Tables.	*Five-figure Tables.*	*Four-figure Tables.*
That for Arg. 6·+	to Arg. 5·+	
" 5·+	" " 4·+	to Arg. 3·+
" 4·+	" " 3·+	" " 2·+
" 3·+	" " 2·+	" " 1·+
" 2·+	" " 1·+	

The methods for arguments larger than 2·, in seven-figure tables, and 1·, in five, and four-figure tables, may be expressed by this *special rule:*

Enter table with the difference of given logarithms, and, for logarithm of the sum, observe the difference between the tabled logarithm nearest to argument, and that of a number one unit greater than the number corresponding to the nearest tabled logarithm, and add this difference to greater given logarithm; for logarithm of difference, subtract the difference between the nearest tabled logarithm and that of a number one unit smaller, from the greater given logarithm.

The foundation of the general rule is

$$log.\,(a \pm b) = log.\, b\left(\frac{a}{b} \pm 1,\right)$$

and that of the special rule is

$$log.\, b \left(\frac{a}{b} + 1\right) = log.\, a + log.\, \left(\frac{a}{b} + 1\right) - log.\, \frac{a}{b},$$

and

$$log.\, b \left(\frac{a}{b} - 1\right) = log.\, a - \left(log.\, \frac{a}{b} - log.\, (\frac{a}{b} - 1)\right)$$

In all cases, $a > b$.

The application of these or other formulas to the solution of the stated problem, by means of the common logarithmic tables, is believed to be now for the first time presented.

LOWELL, MASS., June 1, 1895.

ELECTRICAL SECTION.

Stated Meeting of May 28, 1895.

MR. CARL HERING, President, in the Chair.

TEST OF AN ELECTRIC RAILWAY.

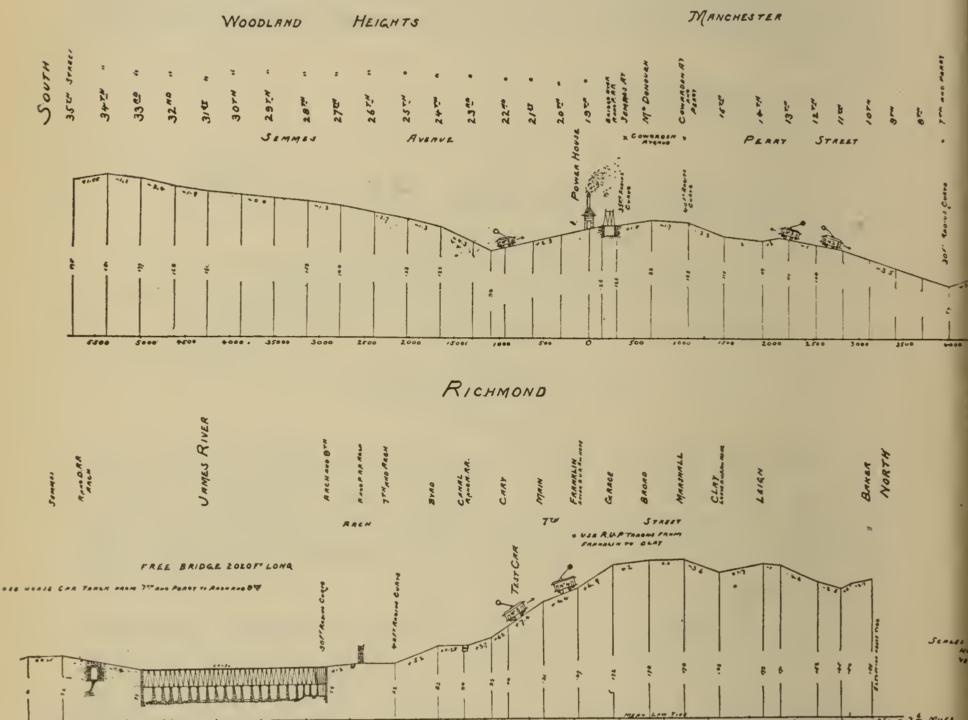
BY A. LANGSTAFF JOHNSTON,

After the interesting and instructive paper we have had on the construction of the ammeter and voltmeter, I have thought it highly appropriate that a few remarks on the practical use of these instruments in electric railway work would be in place.

In the early days of electric railways the data for determining the average amount of current to allow per car could not be had, simply because a road had not been in operation long enough for engineers to make observations on this point.

In 1890 I constructed a line which, for alignment, grades and local conditions, can be classed as a "difficult route," curves 30 feet radius on grades and in narrow streets, grades $7\frac{4}{10}$ per cent., and running over other roads. As the road was operated by one Edison 80 kilowatts generator, driven by one 100 horse-power Ball engine, the equipment consisted of five cars mounted with two 15 horse-power Sprague motors each; all these conditions made it highly favorable

for giving results of practical value. I made a series of tests, not only to determine this point, but the total amount of current leaving the power-house, when the cars were in the most unfavorable combination, *i. e.*, the majority ascending the grades. Although not as extensive and as accurate as I wished, yet I have considered them of sufficient interest to present to you. To accomplish this, on one of the cars



Profile of the Richmond and Southside Electric Railway, showing location of cars when test car No. 5 on maximum grade, by A. Langstaff Johnston, M. Am. Soc. C.E. Nov. 1, 1890.

was placed a Weston portable ammeter and voltmeter, on the other four cars were placed observers with time cards upon which they noted the time of passing previously marked points on the line, all watches being set with the clock at the power-house, where an observer took the reading of the station instruments.

The profile and table which you now have on the screen,

give the general data of one of the tests, and one when the test car was going over the road from the south to the north. The profile shows the location of the other four cars at the very instant the test car was on the centre of the maximum grade ($7\frac{4}{10}$ per cent.), and the table, the data taken on the car and in the power-house during the test.

A study of the table brings out some very interesting points—(1) The maximum amount of current (100 ampères) was at 6·05 P.M., when the test car was on a level and 6,500 feet from the power-house, and using the minimum amount of current (10 ampères). This was caused by the position of the other four cars, the time cards of the observers showing them either on the heavy grades or on the curves. (2) At 5.53 P.M., the test car used the maximum amount of current, and was also on a level and only 300 feet from the power-house; as should be expected, there was no drop in the voltage. It is also seen that the test car, in passing around the curves at Seventh and Perry Streets, Ninth and Arch Streets and Seventh and Arch Streets, took the same amount of current, but with a very large drop in the voltage (80 volts) at Seventh and Arch Streets. At first it was hard to explain this, but by a study of local conditions at this point, I discovered that the motorman had to shut off the current, and did not turn it on until he was in the centre of the curve, when he had to open it up to the seventh notch of the controller to force the car around this 40 feet radius curve, which readily accounts for the large drop that is shown. The same explanation applies to the curve at the Semmes Avenue Bridge; there the car had to cross a narrow bridge at a low speed, on a curve of 35 feet radius. (3) On the maximum grade of $7\frac{4}{10}$ per cent., which was 9,800 feet from the power-house, it took 40 ampères and 440 volts (which was forty volts drop on the line), or $23\frac{1}{2}$ electrical horse-power, to take the test car up the grade at the rate of four miles an hour. The profile shows the test car on this grade, and the location and the direction of travel of the other four cars at this very instant.

These tests show very conclusively the electrical economy that can be gained by a continuous-running motor, which

RECORD OF A TEST MADE OVER THE LINE OF THE RICHMOND AND SOUTHSIDE ELECTRIC RAILWAY, BY A. LANGSTAFF JOHNSTON, C. E., CHIEF ENGINEER, NOVEMBER 1, 1890.

Instruments placed on Car No. 5, and Car run over the East Track from the South End at Thirty-fourth Street and Semmes Avenue, Woodland Heights, to Seventh and Baker Streets, Richmond.

NORTH TRIP.

Time taken on Test Car.	Location of Car on Line.	Weight of Car and Passengers, Pounds estimated.	Rate of Grade per cent.	Length of Grade.	Distance of Test Car from Power House at time Readings were taken—(Feet).	Kind of Rail passed over.	Reading of Meters on Car.		Reading of Meters at Power House.		Horse-power delivered at Power House.	Horse-power developed by Motors in Moving Car.	Drop in Voltage on Line.	Radius of inside Rail of Curve.	Remarks.
P.M.							Ampères.	Volts.	Ampères.	Volts.					
5.45	Thirty-fourth and Semmes Ave.	8,000	+ 1·5	310	5,500	T	20	460	60	480	38·6	12·3	20	—	Grades opposed to car going north, marked thus +
5.50	Semmes Ave. bet. power house and 22d St.	8,000	+ 2·3	1,000	1,000	T	20	460	80	480	51·5	12·3	20	—	
5.53	Curves at Semmes Ave. bridge	8,000	—	—	300	T	45	480	—	480	—	28·9	00	35′	
5.54	Curve at Cowardin and Perry	8,000	—	—	1,100	T	30	460	—	480	—	18·5	20	49′	Grades opposed to car going south, marked thus =
5.55	Fifteenth and Perry, Pass No. 2	8,200	—	—	1,500	T	—	—	80	480	51·5	—	—	—	
6.	Curve at Perry and Seventh	8,200	—	—	4,000	T	40	460	20	480	12·9	24·6	20	39′	
6.01	On Seventh bet. Perry and McDonough . .	8,200	+ 3·	360	4,200	Tram.	30	480	—	—	—	19·3	00	—	Grades are given in feet per 100 (per cent. %).
6.03	South end free bridge, Pass No. 3	8,200	—	—	5,600	Tram.	—	—	—	—	—	—	—	—	
6.05	On free bridge	—	0·0	—	6,500	Tram.	10	445	100	480	64·3	5·9	35	—	
6.06	Curve at Ninth and Arch	—	—	—	7,700	Tram.	40	460	—	—	—	24 6	20	39′	Each car equipped with two 15 h. p. motors (Sprague).
—	Curve at Seventh and Arch	—	—	—	8,500	Tram.	40	400	—	—	—	21·4	80	40′	
—	Seventh between Arch and Byrd	—	+ 5·2	300	8,700	Small grove.	20	440	—	—	—	11·7	40	—	
6.10	Seventh between Main and Cary	—	+ 7·4	300	9,800	Small grove.	40	440	90	480	57·9	23·5	40	—	Maximum grade.
—	Seventh between Franklin and Main .	—	+ 2·0	300	10,400	Small grove.	15	444	—	—	—	8·9	36	—	
—	Seventh between Franklin and Grace . .	8,000	+ 6·9	300	10,800	Tram R.U.P.	25	400	—	—	—	13·4	80	—	{ Richmond Union Pass Track.
6.15	Seventh and Marshall	8,000	—	—	11,700	Tram R.U.P.	—	440	80	480	51·5	—	40	—	
—	Seventh between Clay and Leigh	8,000	+ 1·7	400	12,400	Tram.	20	420	—	—	—	11·2	60	—	

a great many attempts have been made to put in practical operation, but so far without success, and is a line on which inventors can work and experiment in the hope of a large reward, if successful; for it is evident, with a continuous revolving armature there would be only a small drop in the counter E. M. F., whereas, now, every time the motor is started it has to build up, and particularly in cities where the regulations require the cars to come to a full stop at each street crossing, the distances between stops are so short that the armature is revolving at a velocity to be of very little effect for only a few seconds, and really amounts to nothing.

From the profile and table the members of the Section can readily see many other interesting points, but the most important one shown by this test is the necessity of the electrical engineer to study the local conditions in proportioning the feed system of an electric railway, making use of the data given him of former work by his volt- and ampère-meters.

CHEMICAL SECTION.

Stated Meeting of May 21, 1895.

DR. W. C. DAY, President, in the Chair.

[The President announced the paper for the evening, and introduced the speaker.]

THE CITRATE METHOD OF PHOSPHORIC ACID DETERMINATION, WITH SPECIAL REFERENCE TO INSOLUBLE PHOSPHATES.

BY F. BERGAMI.

The molybdate method of phosphoric acid determination has always been regarded as a very safe and accurate method, and its general applicability surely imparts to it an inestimable value as a gravimetric method.

Although some doubts have lately arisen as to its absolute infallibility, for some not yet fully explained reasons,

the only objection usually made to this method is the slow process of its execution.

The chemists of the iron and steel industry, as well as the agricultural chemists, for many years have been looking for a more rapid and still exact method. Of all the propositions made in this regard, those recommending the titration of the molybdate precipitate, either directly by standard alkali, or, after previous reduction by permanganate of potash, have found the most advocates and adherents.

The apparently good results obtained by a method founded on this principle, and which was described in 1893 by Mr. H. Pemberton, Jr., in a paper read before this Section, had induced Dr. B. W. Kilgore, the reporter of the Association of Official Agricultural Chemists of the United States to submit this method in its original form, as well as in a modification recommended by Dr. Kilgore, for investigation to all the chemists who took part in the yearly research of the Association in 1894. The reported results, although not entirely satisfactory, were sufficiently promising to warrant giving the method another trial during the present year.

While this has been the only attempt of the American official chemists to shorten the way of phosphoric acid determination, we find, in looking over the reports of the conventions of the German Agricultural Chemists, that they have successfully solved this problem in a different direction.

Since the abandonment of the old uranium titration method, the German chemists seem to have lost faith in volumetric phosphoric acid determination, and have, therefore, after careful trial, adopted a gravimetric method, based upon the principle that magnesium-ammonium phosphate can be directly precipitated from calcium phosphate solutions, practically free from impurities, if a sufficient quantity of citric acid is present in the solution. This method is now universally used in Germany, and the molybdate method is now only obligatory in cases of arbitration.

The literature accessible to me shows only confirmatory figures of tests made on water-soluble phosphoric acid, and

none in regard to insoluble phosphates. The reports of the conventions of official chemists of the United States mention the citrate method repeatedly, but I have been unable to find in them any record that it has ever been given a practical trial. Those two facts are responsible for the following investigation:

Before starting the investigation, it had first to be decided what was the best way of bringing the phosphates into solution.

Some chemists recommend solution in nitric and hydrochloric acids, while others use sulphuric acid with a small amount of nitric acid. The latter affirm that the method gives better results, if the larger portion of calcium oxide is removed as calcium sulphate, and thus the amount of calcium oxide still left in the solution is made a constant one in all samples. This presumption seems to have a very good foundation, especially in cases of high-grade phosphates with large amounts of calcium oxide. I decided, nevertheless, on solution in nitric and hydrochloric acids, for two reasons: (1) because those acids are used chiefly as solvents for phosphates in our laboratory; and (2) because I thought it interesting to test the method under the most unfavorable circumstances. Therefore, the solution of all samples used in this investigation was effected by boiling 2 grams of the substance with 40 c.c. of concentrated nitric acid and 10 c.c. of hydrochloric acid, and subsequent dilution to 250 c.c.

The citrate solution was prepared strictly according to Prof. Maerker's direction, viz.: 150 grams citric acid are dissolved in water, 500 c.c. of 24 per cent. ammonia added, and the whole brought to a volume of 1,500 c.c. by water.

The first three samples subjected to tests were a refuse bone-black, a bone meal, and a South Carolina phosphate.

Two grams were dissolved in the manner above stated, and the phosphoric acid was determined by the molybdate method.

Aliquot portions, corresponding to 0·2 and 0·4 gram of substance, were mixed with 25 c.c., 50 c.c., 75 c.c. and 100 c.c. of citrate solution, respectively, and, where necessary, suffi-

cient quantities of ammonia added, to provide for about the same alkaline reaction in all cases. After the addition of 25 c.c. of official magnesia mixture, the complete precipitation of magnesium-ammonium phosphate was effected by vigorous stirring with a glass rod for a half an hour, and the precipitate was treated in the usual way.

The results obtained are as follows:

I. REFUSE BONE BLACK, NO. I.

Molybdate Method.

						Per Cent.	*Difference.*
25 c.c.	corresponding to	0·20 gram				35·68	
50 c.c.	"	0·40 "				35·68	

Citrate Method.

						Per Cent.	*Difference.*
25 c.c.	corresponding to	0·20 gram,	25 c.c.	citrate	solution	36·00	+ ·32
25 c.c.	"	0·20 "	50 c.c.	"	"	35·74	+ ·06
25 c.c.	"	0·20 "	75 c.c.	"	"	35·68	
25 c.c.	"	0·20 "	100 c.c.	"	"	35·52	— ·16
50 c.c.	"	0·40 "	50 c.c.	"	"	36·08	+ ·40
50 c.c.	"	0·40 "	75 c.c.	"	"	35·76	+ ·08
50 c.c.	"	0·40 "	100 c.c.	"	"	35·60	— ·08

II. BONE MEAL, NO. I.

Molybdate Method.

						Per Cent.	*Difference.*
25 c.c.	corresponding to	0·20 gram				22·40	

Citrate Method.

						Per Cent.	*Difference.*
25 c.c.	corresponding to	0·20 gram,	25 c.c.	citrate	solution	22·56	+ ·16
25 c.c.	"	0·20 "	50 c.c.	"	"	22·40	
25 c.c.	"	0·20 "	75 c.c.	"	"	22·24	— ·16
25 c.c.	"	0·20 "	100 c.c.	"	"	22·24	
50 c.c.	"	0·40 "	50 c.c.	"	"	22·64	+ ·24
50 c.c.	"	0·40 "	75 c.c.	"	"	22·40	
50 c.c.	"	0·40 "	100 c.c.	"	"	22·32	— ·08

III. SOUTH CAROLINA ROCK.

Molybdate Method.

						Per Cent.	*Difference.*
25 c.c.	corresponding to	0·20 gram				26·56	

Citrate Method.

						Per Cent.	*Difference.*
25 c.c.	corresponding to	0·20 gram,	25 c.c.	citrate	solution	27·04	+ ·48
25 c.c.	"	0·20 "	50 c.c.	"	"	26·72	+ ·16
25 c.c.	"	0·20 "	75 c.c.	"	"	26·56	
25 c.c.	"	0·20 "	100 c.c.	"	"	26·24	— ·32
50 c.c.	"	0.40 "	50 c.c.	"	"	26·95	+ ·40
50 c.c.	"	0·40 "	75 c.c.	"	"	26·64	+ ·08
50 c.c.	"	0·40 "	100 c.c.	"	"	26·56	

The results show that the success of the method depends chiefly on the amount of citrate solution brought into action upon the phosphate. If the amount falls below a certain limit, the results become considerably too high, while a large excess of citrate solution tends to render the results a little too low. The high figures are undoubtedly due to a contamination of the magnesium-ammonium phosphate, and the low figures must be caused by incomplete precipitation.

Some chemists are of the opinion, that the co-precipitation of some SiO_2, CaO and possibly Fe_2O_3 and Al_2O_3, can never be prevented, while at the same time the dissolving action of the citric acid upon those oxides is always somewhat extended to the ammonium-magnesium phosphate also, and causes incomplete precipitation. The best results are obtained when the quantity of the citrate solution is such that the error through contamination is just compensated by the error through incomplete precipitation.

Other chemists assert that a sufficient quantity of citrate solution will prevent any contamination of the precipitate, and claim that the best results are obtained by an amount of citrate solution just large enough to keep all impurities in solution, and still not too large to exert any dissolving influence upon the precipitate, which, in such case should consist of pure magnesium-ammonium phosphate.

Here is a disagreement, and while it may be very interesting and even necessary, for scientific reasons, to know the real sources of error, it is immaterial for the practical applicability of the method, if only that certain amount of citrate solution can be ascertained which will secure good or at least approximately good results. A close observation of the above-stated figures reveals the fact that, with phosphates containing about from twenty to thirty-five per cent. phosphoric acid, results by the citrate method agree very well with those by the molybdate method, when from 50 to 75 c.c. of citrate solution are employed on 0·2 gram of substance, or from 75 to 100 c.c. on 0·4 gram.

The tests were now continued on some superphosphates and ammoniated superphosphates, with the following results:

AMMONIATED PHOSPHATE, NO. 1.

	Per Cent.
Molybdate Method	11·68
Citrate Method:	
50 c.c. corresponding to 0·40 gram, 50 c.c. citrate solution	11·76
50 c.c. " 0·40 " 75 c.c. " "	11·68
50 c.c. " 0·40 " 100 c.c. " "	11·52

AMMONIATED PHOSPHATE, NO. 2.

Molybdate Method	11·28
Citrate Method:	
50 c.c. corresponding to 0·40 gram, 50 c.c. citrate solution	11·28
50 c.c. " 0·40 " 75 c.c. " "	11·12
50 c.c. " 0·40 " 100 c.c. " "	11·04

ACIDULATED SOUTH CAROLINA ROCK.

Molybdate Method	15·84
Citrate Method:	
50 c.c. corresponding to 0·40 gram, 50 c.c. citrate solution	15·92
50 c.c. " 0·40 " 75 c.c. " "	15·76
50 c.c. " 0·40 " 100 c.c. " "	15·68

PURE DISSOLVED BONE.

Molybdate Method	16·80
Citrate Method:	
50 c.c. corresponding to 0·40 gram, 50 c.c. citrate solution	16·88
50 c.c. " 0·40 " 75 c.c. " "	16·72

Those tests on phosphates containing less than twenty per cent. of phosphoric acid indicate that an amount of 50 c.c. to 75 c.c. of citrate solution used on 0·4 gram of substance is the most favorable to the accuracy of the method.

Taking these results, together with those obtained on phosphates containing more than 20 per cent. phosphoric acid, we must conclude that an average amount of 75 c.c. of citrate solution acting on 0·4 gram of substance will give very good results on phosphates of all grades.

In all tests made so far, the average difference from the molybdate method does not exceed ± 0·10 per cent., when 0·40 gram of substance and 75 c.c. of citrate solution are used. The only case in which I fear the — difference may grow a little higher, is that in which the amount of phosphoric acid falls considerably below 10 per cent.; for instance, down to 5 per cent. or 4 per cent.; but as such a small percentage of total phosphoric acid is a comparatively rare occurrence, it may at present be neglected.

It will be shown later, by tests on citrate-insoluble phosphoric acid, that in cases where only a small amount of phosphoric acid is present a reduction of the quantity of citrate solution is necessary. The investigation on total phosphoric acid was previously ended with the following tests:

REFUSE BLACK, NO. 2.

	Per Cent.
25 c.c. corresponding to 0·20 gram, molybdate method	29·60
25 c.c. " 0·20 " 50 c.c. citrate solution . .	29·60

BONE MEAL, NO. 2.

	Per Cent.
25 c.c. corresponding to 0·20 gram, molybdate method	21·76
25 c.c. " 0·20 " 50 c.c. citrate solution . .	21·85

FLORIDA PHOSPHATE.

	Per Cent.
25 c.c. corresponding to 0·20 gram, molybdate method	32·32
25 c.c. " 0·20 " 50 cc. citrate solution . .	32·48

EXPORT BONE.

	Per Cent.
50 c.c. corresponding to 0·40 gram, molybdate method	12·64
50 c.c. " 0·40 " 50 c.c. citrate solution . .	12·64

AMMONIATED PHOSPHATE, NO. 3.

	Per Cent.
50 c.c. corresponding to 0·40 gram, molybdate method	11·92
50 c.c. " 0·40 " 50 c.c. citrate solution . .	12·00

AMMONIATED PHOSPHATE, NO. 4.

	Per Cent.
50 c.c. corresponding to 0·40 gram, molybdate method	11·76
50 c.c. " 0·40 " 50 c.c. citrate solution . .	11·76
50 c.c. " 0·40 " 100 c.c. citrate solution . .	11·60

ACIDULATED SOUTH CAROLINA ROCK, NO. 2.

	Per Cent.
50 c.c. corresponding to 0·40 gram, molybdate method	16·00
50 c.c. " 0·40 " 50 c.c. citrate solution . .	16·08

ACIDULATED SOUTH CAROLINA ROCK, NO. 3.

	Per Cent.
50 c.c. corresponding to 0·40 gram, molybdate method	16·32
50 c.c. " 0·40 " 75 c.c. citrate solution . .	16·24

The last line of tests shows that the method, under certain circumstances, allows of a little modification. For instance, the analyst who has to control the manufacture of fertilizers generally knows the approximate amount of phosphoric acid contained in the product which he has to examine. He may, therefore, when working on

high-grade phosphates, prefer to use only 50 c.c. of citrate solution on 0·2 gram of substance, instead of the average amount of 75 c.c. on 0·4 gram of substance. The reason why I consider it an advantage to employ only so small a portion as 0·2 gram is that in some dark-colored phosphate solutions a little organic matter is thrown down together with the magnesium precipitate.

In such a case it takes much longer to burn the precipitate to perfect whiteness, when the latter forms a larger bulk, for instance, of 0·25 gram, than when it amounts to only one-half of this volume.

Solution in sulphuric acid and some nitric acid, as recommended by many chemists, may render my objection to the use of 0·4 gram of substance unnecessary, as it will very likely produce a more perfect oxidation of the organic matter, and a nearly colorless solution. Besides this, it removes a large part of the calcium oxide, which will probably lessen the source of error. I intend to make tests in this regard in the near future.

Wherever the percentage of the phosphate is known not to exceed 16, an amount of 50 c.c. citrate solution to 0·4 gram of substance seems to be sufficient, and may, especially where the phosphoric acid falls considerably below 10 per cent., be preferable to the employment of 75 c.c., as it would tend to reduce the error arising from incomplete precipitation.

No experiments were made by the writer in regard to the amount of magnesia mixture. The German practice is to use 25 c.c. in all cases, and this rule was strictly followed. A large excess of magnesia mixture seems to be necessary to neutralize the dissolving influence of the citrate solution upon the ammonium-magnesium phosphate. O. Reitmair (*Zeitschrift fuer angew. Chemie*, 1889, 702) supposes that a soluble double compound $Mg.NH_4.\ PO_4.\ (NH_4)_3.\ C_6\ H_5O_7$ is formed, which can only be decomposed if more magnesium chloride is present than can combine with the ammonium citrate to form $Mg.\ NH_4.\ C_6\ H_5O_7$.

The results, in respect of total phosphoric acid, had been so satisfactory that I hardly doubted that the method would

work just as well on the citrate-insoluble phosphoric acid. How far my expectations were substantiated will be shown by some tests, which were conducted in the following manner: 2 grams of an acidulated phosphate were treated with water and neutral citrate of ammonia solution, according to the official method; the residue and filter dissolved in 40 c.c. of nitric acid, and 10 c.c. of hydrochloric acid, and the solution brought to a volume of 200 c.c. In 50 c.c., corresponding to 0·5 gram of the original substance, the phosphoric acid was determined by the molybdate method. Another portion of 50 c.c. was mixed with 40 c.c. of citrate solution and made strongly alkaline by 20 c.c. of ammonia, sp. gr. 0·90. After the addition of 20 c.c. of magnesia mixture, the precipitation of ammonium-magnesium phosphate was effected by stirring for one-half hour. The filtration was executed after the lapse of different periods of time, as specified in the following table:

	Molybdate Method.	Citrate Method. *Filtration immediately after stirring.*	Citrate Method. *Filtration after 2 hours' standing.*
	Per cent.	*Per cent.*	*Per cent.*
Ammoniated phosphate, No. 1 . .	2·94	2·81	2·88
" " " 2 . .	2·17	1·98	2·04
" " " 3 . .	4·73	4·60	4·60
" " " 4 . .	3·20	3·00	3·13
		Filtration after 2 hours' standing.	
Ammoniated phosphate, No. 5 . .	4·41	4·35	
" " " 6 . .	3·32	3·32	
Acidulated bone	2·17	2·11	
		Filtration after 24 hours' standing.	
Acidulated bone	4·22	4·22	
Ammoniated phosphate, No. 7 . .	4·09	3·96	
Acidulated South Carolina rock, .	3·52	3·45	
" " " " .	1·40	1·28	

In the above tests, 40 c.c. citrate solution were used. In the following tests, this quantity was reduced to 25 c.c.:

	Molybdate Method. Per cent.	Citrate Method. *Filtration after 2 hours' standing.* Per cent.
Ammoniated phosphate, No. 8	3·58	3·64
" " " 9	3·90	3·96
Acidulated South Carolina rock	1·40	1·34

In the determination of such small amounts of phosphoric acid it seems to be advisable to give the precipitate a little more time for development than in case of the total phosphoric acid, where it does not make any difference whether the precipitate is filtered at once after the stirring or at any later time. Two hours seem to be enough for this purpose, as the results after twenty-four hours fail to show any better agreement.

It appears that an amount of 40 c.c of citrate solution is still a little too large. The average of the results is a little lower than those by the molybdate method, and none of them are any higher. With a reduction of the citrate solution to 25 c.c., the results seem to get a little higher than by the molybdate method.

I believe that the most favorable proportion between substance and citrate solution will be 100 c.c., corresponding to 1 gram of the original substance and 50 c.c. of citrate solution.

I have not yet made any tests to confirm this supposition, as lack of time has prevented me at present from taking into consideration every possibility of modification and application of the method. For instance, another point of interest, which was not touched by this investigation, is the determination of extremely small amounts of phosphoric acid. The citrate-insoluble residue of some superphosphates, especially of those made from refuse bone-black, frequently contains no more than 0·1 to 0·3 per cent. of phosphoric acid, and it is very likely that in the determination of such small amounts the citrate method will prove to be a failure unless the quantities of substance and of the neutral citrate solution for extraction, as directed by the official method, are raised considerably.

In conclusion, I wish to make a few remarks in regard to the execution of the method.

The citrate solution exerts a somewhat retarding influence upon the precipitation, which must be overcome by stirring, to insure complete precipitation within a reasonably short time.

The German usage is to stir for one-half hour, and I believe that this length of time should never be shortened, for safety's sake. The errors to which an insufficient stirring can lead may be illustrated by the following test, viz.:

25 c.c. (= 0·2 gram of substance of the bone meal, No. 1), after adding 100 c.c. of citrate solution and 25 c.c. of magnesia mixture, were stirred only until the precipitate had appeared (about two minutes), and the latter filtered after the lapse of one-half hour.

The result was 21·12 per cent., as compared with 22·24 per cent., obtained by vigorous stirring for one-half hour. Of course, the proportion of 100 c.c. of citrate solution to 0·2 gram of substance was an extreme one, and I believe that wherever an amount of 75 c.c. is used on 0·4 gram of substance, the danger of incomplete precipitation is not quite so great, but it still exists.

The determination of citrate-insoluble phosphoric acid will be rendered absolutely unreliable by insufficient stirring, unless the precipitate is allowed to stand a long time before filtration.

Many propositions have been made to shorten the time of stirring—for instance, by the use of a feather with the barbs cut short, instead of a glass rod, or by adding some pulp of ashless filter paper, etc.—but as I have not tried any of them, I cannot judge of their reliability.

The objection has been made to the use of a glass rod that, as it is impossible to avoid coming in contact with the wall of the beaker, some portion of the precipitate will adhere firmly to the glass and can only be removed with difficulty. I must state that I never had any trouble in transferring the last traces to the filter by using a rubber-tipped glass rod for removing the adhering parts of the precipitate from the glass. In routine work the stirring must certainly be done by mechanical means.

While it may appear unnecessary and even ridiculous to dwell at length upon so simple an operation as the filtration of a precipitate, I can nevertheless not refrain from passing some remarks on this subject, for the reason that the filtration of the ammonium-magnesium precipitate is the only operation of the method which may cause some difficulty.

This precipitate, as obtained in presence of citric acid, is in a very fine form and has a strong tendency to pass through the filter. Therefore, great care must be taken in constructing a good filtering medium when a suction pump is used.

If the filtration be executed without pressure, it will be found necessary to employ two Schleicher & Schuell filter papers.

With the use of such a double filter I have not experienced any trouble in obtaining crystal-clear filtrates.

While on some voluminous precipitates, as, for instance, the molybdate precipitate, the loss, indicated by a slight turbidity of the filtrate and wash water, will not involve any appreciable error and may be neglected, such an inaccuracy should not be tolerated in the execution of the citrate method. Here the precipitate is in so compact a condition, even more than when obtained by the molybdate method, that a loss, which, by judging the turbidity of the filtrate, appears very small, may prove to be of serious consequence.

Wherever a large number of analyses is being carried on at once and no special attention paid to each single determination, the danger is great, that, for the reason just stated, losses of 0·10 per cent. to 0·20 per cent., and even more, may occur.

The sometimes enormous differences which appear in comparing the results of different analysts by methods considered most accurate and trustworthy by all leading chemists, must arouse the suspicion that the same are at least partly due to some neglect in the execution of such minor operations as, for instance, the filtration and washing of a precipitate.

This investigation is not presented as an exhaustive one. The tests are not numerous enough and not carried out systematically enough to allow a decisive judgment to be passed upon the method.

The samples analysed represent only phosphates of nearly the same character. The amount of SiO_2, Fe_2O_3 and Al_2O_3 present in most of them is extremely minute, and, even in the sample of South Carolina rock, comparatively small. Therefore, the tests will have to be extended to phosphates containing those and other bodies, which might possibly influence the method when present in larger quantities. It will further be of interest to find out if the use of sulphuric acid and some nitric acid, as solvents, would be of any considerable advantage.

The comparison of the citrate method with the molybdate method was made under the supposition that the results by the latter were correct. It has long been suspected, and the last year's investigation of the molybdate method by the Association of Official Agricultural Chemists of the United States, indicates strongly that the results by this method in its present form are a little too high. The plan submitted for this year's work of the Association, by Dr. B. W. Kilgore, will probably produce a sure proof of this error. In such case the results of the citrate method obtained by the action of 75 c.c. of citrate solution on 0·40 gram of substance would be too high also, and an increase of the quantity of citrate solution would probably be advisable.

The only possible way to secure a working plan of the citrate method, which would give general satisfaction, is by the coöperation of a larger number of American chemists. The hope of giving an impulse to such coöperative work, was the sole object of this investigation, which may be nothing more than a repetition of work done by others long ago.

It can hardly be expected that the citrate method, in the extremely simple form used for the tests above, will ever give absolutely correct results. The employment of the same quantity of citrate solution on all kinds of phosphates

with a widely varying percentage of phosphoric acid, will always tend to give results a little higher on high-grade phosphates and on those containing larger amounts of SiO_2, CaO, etc., than on low-grade phosphates and those with less impurities.

Still, as long as as it can be proven that with ordinary care the errors can be kept inside of limits which allow the use of the method for nearly all practical purposes, I do not see any reason why the same should not be given a place alongside of them olybdate method,especially under the consideration of the great discrepancies in the results of the latter method, obtained by different chemists on the same sample.

NOTES AND COMMENTS.*

THE NEW CANADIAN "SOO" CANAL.

In the Secretary's annual report, printed in the *Journal* for February, reference was made to the enterprise of the Dominion authorities in endeavoring to secure for that country a complete chain of navigable waterways connecting the great lakes with the ocean, on Canadian territory. The last link in this chain has been supplied by the completion of the Canadian "Soo" Canal, which was formally opened for traffic on June 13th.

The following reference to the subject from *The Press*, of Philadelphia, treats of it in an interesting way:

The new Canadian canal around the Falls of the River St. Mary, which joins Lakes Superior and Huron, will be opened to-day, and another one of the enterprises which mark the closing years of the nineteenth century will be practically finished. This is the canal the British Government has been building for some years past so as to give it an independent route from the Atlantic Ocean to the upper lakes. It has been cut through St. Mary's Island, on the Canadian side of the St. Mary's River Rapids, for 3,500 feet, the whole canal being 18,100 feet long, 152 feet wide at the surface, 145 feet wide at the bottom and with a navigable depth of at least twenty feet. The lock is 900 feet long, sixty feet wide and twenty-two feet deep, and will accommodate three vessels at once.

This canal is entirely distinct from the canal the United States Government is building on the Michigan side of the St. Mary's Falls. The latter will not be completed for a year yet, but in some respects it will be more commodious than the Canadian canal. The lock in the American canal now in use is only 515 feet long, eighty feet wide and twenty-one feet deep, but

* From the Secretary's monthly reports.

the new lock which will be finished soon will have a length of 800 feet, a breadth of 100 feet and a depth of twenty-one feet, and it will be able to accommodate four vessels at one time. This, with the construction of the channel 300 feet wide and twenty feet deep, below the Falls, and which will save a distance of eleven miles, will make the most complete passage-way between Lakes Huron and Superior. The British canal has cost about $5,000,000, while the cost of the American canal is estimated at $4,740,000.

The different methods employed by the American and British Governments when a great public improvement is demanded are well illustrated in the building of these two canals around the rapids of St. Mary's River. The British canal was begun and finished in about five years, but the American canal was begun nearly fifty years ago and patching has been going on ever since. In the meanwhile commerce by this route has been vastly increased until the tonnage passing through the Sault Ste. Marie locks greatly exceeds the tonnage of the Suez Canal, notwithstanding the fact that the latter is open all the year and the former an average of about 250 days in the year. During last season 10,208 steamers and 3,676 sail vessels carrying 13,110,366 registered tons of freight passed through the canal. This was an increase of more than 3,000,000 tons over the previous season. The cost of moving freight through the canal last year was less than 1 cent per ton per mile.

With the opening to-day of the new canal around the Falls of the St. Mary's River the Dominion will have an uninterrupted route from the western end of Lake Superior to the Atlantic Ocean. The only way the United States can match this enterprise is by enlarging and deepening the Erie Canal through New York State.

AN APPARENTLY NEW OBSERVATION IN ELECTROLYSIS.

E. Andréoli, in a recent impression of *Le Génie Civil*, gives a brief description of an interesting and apparently new phenomenon in electrolysis, and which he has utilised in effecting the electrolytic deposition of metals and the decomposition of salts. He defines the method by the term "indirect electrolysis."

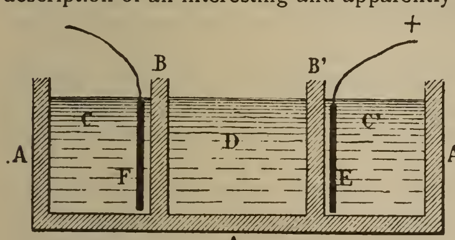


FIG. 1.

The nature of the phenomenon alluded to will be made apparent by the following description, viz.:

Assume that the central compartment *D*, of a chamber *A*, divided into three parts by two porous partitions *B B'* (*Fig. 1*), be filled with a (conducting) solution of any kind, while the lateral compartments *C C'*, have an anode *E* and a cathode *F*, immersed respectively in an electrolyte, which may be the same in both, or different in each. Under these conditions electrolysis in *C C'* proceeds the same as if the central compartment were absent, the solution in this compartment remaining unaffected by the electrolytic

action taking place in the two lateral compartments. It undergoes no change, but, on the contrary, remains inert, notwithstanding the decomposition of the anolyte and catholyte, respectively, in the adjacent lateral compartments. But if a metallic plate, or several of them, be introduced in the solution of the central compartment *D* (*Fig. 2*), electrolytic action at once begins.

M. Andréoli believes that he has been the first to observe and utilise this phenomenon, which he defines as "indirect or secondary electrolysis."

The following example will serve to illustrate the method in practice:

Let it be assumed that the compartments *C C*, on the right and left, are supplied with a solution of common salt, and that the middle one contains a solution (either concentrated or dilute) of cyanide of gold. On the positive side, *C′*, there is an anode of retort carbon, and on the other, *C*, a cathode of iron.

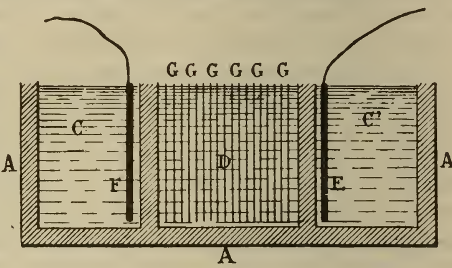


FIG. 2.

As soon as the current is established in the vessel *A*, electrolytic decomposition takes place, with the liberation of chlorine at the positive electrode *E*, and of caustic soda at the negative electrode *F*, and the solution of cyanide of gold in *D* is not affected by the migration of the ions.

If, however, a metal plate, or, preferably, a number of such plates, *G G G G*, be immersed in the solution of the central compartment, there will take place a deposition of gold upon these plates, notwithstanding that they are not connected with either the positive or the negative pole of the generator of electricity, or with the anode or the cathode in the adjacent compartments. Neither chlorine from the compartment *C* nor soda from the compartment *C′* will enter the central compartment *D* (*sic*), and contaminate the gold solu-which last, according to the density of the current and the number of plates, will be exhausted of gold more or less rapidly.

The section of liquid which faces the diaphragm of the negative compartment should be positive, and, in proof of this, it is found that the surface of a lead plate facing this diaphragm will become completely peroxidized, while the other side will become covered with a coating of gold.

Such is the description given by M. Andréoli, of the general features of the operation of "indirect electrolysis." The specific modification of the foregoing experiment, given in what immediately follows, is equally novel and interesting, and (assuming the facts to be correctly reported) more difficult of satisfactory explanation, viz.:

Says the author: "I have replaced the salt solution of the positive and negative compartments *C C′* with a solution of cyanide of gold identical with that in the central compartment *D*. The anode was a plate of lead, the cathode one of iron. After the lapse of several days, I removed 100 c.c. of the solution from the lateral compartments, which I evaporated to dryness, then collected, scarified and cupelled the residue, and was able to confirm

the fact that the quantity of gold obtained was absolutely the same as that found in 100 c.c. of solution of gold before treatment. On the cathode there was not a trace of gold, consequently there was no such deposition of gold as takes place in the ordinary galvanoplastic operations; whereas, during the period of the experiment, I have been able practically to exhaust of its metal 100 liters of the gold solution in the central compartment."

Although it is not stated in terms that the electrolyte in this experiment was acted upon, during the several days spoken of, by a current from an external source of electricity, the context would seem to make this assumption necessary. How it comes to pass that the electrolyte in the lateral chambers in which anode and cathode are immersed suffers no decomposition, while that in the central chamber, which is quite independent of metallic connection with either anode or cathode, or with the source of current, is not clear. The difficulty is not lessened if it be assumed that the installation of the lateral cells acted as a primary battery.

M. Andréoli proceeds to describe other examples of his method of "indirect electrolysis." One of these, which may possibly find practical application, relates to the decomposition of bisulphite of sodium for the production of nascent hyposulphurous acid for bleaching purposes. The decomposition of the sulphites and bisulphites, by the ordinary electrolytic methods is impracticable. but, according to M. Andréoli, it is accomplished by the indirect method with ease and rapidity. For the details of this particular procedure, the reader is referred to the original source (*vide Le Genie Civil*, July, 1895, p. 137).

The facts observed and ingeniously utilised by this author appear to be novel. While apparently anomalous, they will doubtless prove to be susceptible of satisfactory explanation without doing violence to accepted explanations of electrolytic phenomena. W.

TECHNICAL NOTES.

Gesner's method of *protecting iron and steel against rust*, which is described in *La Revue Scientifique* consists in forming on the surface of the metal a double carbide of hydrogen and iron, which is extremely hard and adherent. In fact, a bar thus coated can be bent through an angle of forty-five degrees without disturbing the layer. In carrying out the process, the articles are thoroughly cleaned from rust, but it is not indispensable to remove all oil or grease. A couple of gas retorts are placed alongside each other, and raised to a temperature of from 600° C. to 700° C. The articles to be treated are then placed in these retorts for about twenty minutes, after which a current of hydrogen is passed through the retorts for forty-five minutes. A small quantity of naphtha isthen introduced, the supply being maintained for ten minutes. It is then stopped, the current of hydrogen being kept up fifteeen minutes longer, when it is stopped and the retorts allowed to cool to 400° C., and when this temperature is reached the doors can be opened and the finished product removed. The coating thus given has a bluish color.

In some recent tests of the Marsden *cornstalk cellulose* and English cocoa

cellulose, made at Indian Head proving grounds, the results were in favor of the former. The Marsden material is made of the pith of cornstalks. It was made into a cofferdam and shipped to the proving grounds. A cofferdam of the English product was also made and it was sent to the proving grounds. There the two were set up side by side, and a six-inch and an eight-inch shell fired into each. The interior of the dams was then filled with water, and it was found that both practically held all the liquid. After a short time, however, a few drops of water were seen to trickle through the cocoa cellulose, but none penetrated the cornstalk product.

An artificial rubber of more or less strength may be obtained by dissolving four parts of nitro-cellulose in seven parts of bromo-nitro-toluol. Upon varying the proportion of the nitro-cellulose, there may be obtained a material possessing elastic properties and much resembling india-rubber, and even gutta-percha. Nitro-cumol and its homologues may, if desired, be used instead of bromo-nitro-toluol. *Invention* describes another substitute for india-rubber lately discovered by E. Desprez, of Paris. Gutta-percha, in the form of sheet, is taken and covered on one or both sides with a close-meshed fabric—even wire gauze will serve for some purposes—and the whole is agglomerated by pressure under heat. Sawdust, zinc dust and other suitable and cheap materials may, it is understood, be incorporated with the gutta-percha.—*Phar. Jour.*

A composite steam pipe, which, its designer claims, meets the requirements of increasing pressures, and at the same time possesses the advantages of a copper pipe, has been patented by Mr. R. D. Smillie, electrical engineer, Glasgow. As described in the *Engineering and Mining Journal*, it consists of a shell of copper of sufficient strength to withstand the longitudinal stresses produced by any given pressure of steam acting on the sectional area of the pipe. The circumferential stresses are provided for by a coil of steel wire, having a high tensile strength, being wound closely round and in intimate contact with the shell. The fibre of the coil is at right angles to the circumferential stresses, avoiding the risks common to pipes with brazed or welded joints and to drawn pipes where the fibre of the metal, being parallel to the circumferential stresses, is in the least effective position for resistance. The steel coil is wound on the shell while it is rotating in a bath of molten alloy, the melting point of the alloy being sufficiently high to be unaffected by the temperature of steam of high pressure, and by this process shell and coil are fused into a solid mass.

In a recent issue of *L'Industrie*, M. Villon describes the use of liquid sulphurous acid, as practised in Germany, for the *purification of oils*. The oil to be purified is put in a cylindrical boiler of double sheet lead, furnished with a paddle agitator or any other improved device. There is introduced

into the oil, by a tube, ·05 to 1·00 per cent. of liquid anhydrous sulphurous acid, which is immediately vaporized and acts upon the albuminous and proteic coloring matters of the oils. To stimulate and complete the reaction, heat is supplied by steam in a worm pipe. This produces an increase of pressure, indicated by a manometer, but which ought not to exceed 13·7 pounds per square inch. The mixture is allowed to cool and the reaction prolonged several hours, after which it is washed a number of times with warm water and filtered. This process appears to give good results; the oil obtained is clear, slightly yellowish and very bright; it burns well without carbonising the wick, or acts as a lubricant without forming coom. The waste of this process is not great, and the oil retains its valuable qualities several months. Attempts have been made to combine the purification by chloride of zinc with that by sulphurous acid, and the results are more complete. When the chloride of zinc is used it is necessary to wash the oil well, for the presence of but a small quantity of this material, left in the oil, opposes combustion. The oil is first agitated with the chloride in solution as a syrup, and then the whole is treated with sulphurous acid, as has been explained.

ELECTRIC RAILWAYS IN THE UNITED STATES.

Mr. Joseph Wetzler, a well-known electrical engineer, in an interesting article on the growth of the electric railway system in the United States, contributed to a recent impression of *Scribner's Magazine*, is authority for the statement that there are at the present time 850 electric railways in the United States, operating more than 9,000 miles of track, with 2,300 cars, and representing a capital investment of $400,000,000.

An idea of the rapidity and magnitude of the extension of this system of traction may be formed when the fact is noted that, in 1887, the electric roads in the United States numbered only thirteen, with about 100 cars in operation.

MAGNETIC PROPERTIES OF IRON, NICKEL AND MAGNETITE AT DIFFERENT TEMPERATURES.

M. Curie, who has been investigating the magnetic properties of bodies at different temperatures, has published the results of his studies of iron, nickel and magnetite, in a recent impression of the *Journal de Physique*, an abstract of which, from London *Nature*, is given herewith. The important bearing of these researches upon the practical solution of the problem of the thermo-electric generator lends to them a special interest.

"The present paper deals with iron, nickel and magnetite. In the case of iron, measurements have been made at temperatures between 20° C. and 1,360° C., and for field strength of from 25 to 1,350 C.G.S. units. The observations on nickel and magnetite were only made at temperatures above that at which the great change in the magnetic properties of these bodies takes place. The values obtained with iron up to about 756° C. agree with those

previously obtained by Dr. Hopkinson. Above this temperature the author finds that the curves showing the relation between the intensity of magnetisation (I) and the strength of the field are straight lines passing through the origin for temperatures between 750° and 1,280° F. decreases more and more slowly. At first, (I) decreases to half its value for a rise of temperature of a few degrees, but between 950° and 1,280°, the susceptibility is almost a constant, only decreasing very little as the temperature rises. At a temperature of about 1 280°, the susceptibility suddenly increases by about 50 per cent., and then again gradually decreases up to 1,365°. The author, with some hesitation, gives the following explanation of this behavior: 'Up to a temperature of 860°, iron behaves like any other paramagnetic body. At a temperature of about 860°, however, it begins to change into a second allotropic form, this transformation being complete at about 920°, the iron remaining in this condition up to 1,280°, and behaving like such a body as oxygen or palladium. Finally, at 1,280°, the iron changes suddenly back to its first condition.' The attractiveness of the above theory can only be appreciated by a study of the author's curves, for if the curve showing the connection between the logarithm of the susceptibility and the logarithm of the temperature is plotted, it is found that the curve between 750° and 860° would, if prolonged, form, with the curve above 1,280°, a curve in all respects similar to the curves obtained in the case of nickel and magnetite. With nickel the author finds that the temperature of the magnetic transformation is about 340°. Above this temperature the susceptibility is independent of the strength of the field, and decreases regularly and very rapidly as the temperature rises. In the case of magnetite the chief magnetic transformation takes place at a temperature of 535°. At temperatures between 550° and 1,370° the susceptibility is independent of the strength of the field and decreases regularly, and between 850° and 1,360° varies inversely as the absolute temperature. The value of K (see previous note, *loc. cit.*) being given by the expression

$$K = \frac{0{\cdot}0280}{T}$$

where T is the absolute temperature. From the differences exhibited by the behavior, with change of temperature of diamagnetic and paramagnetic bodies, the author considers that these two properties must be attributed to different causes."

ELECTRICITY *vs.* STEAM ON RAILROADS.

Mr. Frank Sprague, an electrician whose opinions on the subject are entitled to the highest respect, contributes an interesting paper on the above subject to a recent impression of the *Engineering Magazine*. In the course of this the author expresses the belief that electricity will only in part take the place of the steam locomotive for railway service, and then only when the number of units operated between terminal points is so large that the resulting economy will pay a reasonable interest on the combined cost of a central tation system of conductors and the motor equipment, and the traffic existing is commensurate with the needs of such a system. "Let us lay aside,

then," he says, "some of the visionary prophecies concerning electric railways. Perhaps no one has been more actively identified with them than myself; no one, I think, has greater faith in the future of the electric railway than I; but its future is not in the wholesale destruction of existing great systems; it is in the development of a field of its own, with recognized limitations, but of vast possibilities. It will fill that field to the practical exclusion of all other methods of transmitting energy; it will replace the locomotive on many suburban and branch lines; it will operate almost all street railway systems and elevated and underground roads; it will prove a valuable auxiliary to trunk systems; but it has not sounded the death-knell of the locomotive any more than the dynamo has sounded that of the stationary steam engine. Each has its own legitimate field, which will play its proper part in the needs of all civilization."

BOOK NOTICES.

Pray's Steam Tables and Engine Constants, for Facilitating all Calculations upon Indicator Diagrams, or Various Problems Connected with the Operation of the Steam Engine, from reliable data, with precision. By Thomas Pray, Jr., C.E. and M.E. New York: D. Van Nostrand Company. 1895.

Those engineers who have followed Mr. Pray in his methods of determining the power of steam engines by the indicator, will find this volume of tables a valuable continuation of his "Twenty Years with the Indicator." The eighty-five pages of tables contained in this volume and the accompanying forty-one pages of explanatory text, if as accurate as they seem to be in all respects, cannot fail to form a valuable assistant, particularly to young engineers who have not entirely familiarized themselves with all that has been written upon this subject.

The tables are so arranged as to be readily used, the first being the "Ratio of Expansion, Cut-off, etc.," with hyperbolic logarithm, capable of being read across the page for all computations; the first column gives Cut-off; second, Ratio of Expansion for Cut-off in Column 1; third, Hyperbolic Log. + 1 of ratio of expansion in Column 2; fourth, Vega's Log. of Column 3; fifth, Constant for Mean Exerted Pressure at Cut-off in Column 1; sixth, Vega's Logs., Column 5. In relation to this table, the text calls particular attention to the necessity of computing the total amount of clearance, and is clearly expressed, as also is the method of arriving at the gain from expansion.

The second table, pp. 23–36, gives the Heat Units in Water, 32° F. to 212° F., followed by Factors of Evaporation, the equivalent of (from and at 212° F.). In the text, this is followed by notes on the economy of feed water heating. Table No. 4, pp. 39–45, gives the Heat of Steam, the first column giving temperature of the steam in Fahrenheit degrees; column "H" gives

total heat of steam from 32° F.; "L," latent heat of vaporization from 32° F.; "P," pounds per square inch at 45° latitude, sea level, mercury at 32° F.; "h," heat of the liquid from 32° F. In this table, the points marked with (x) are the points of Regnault's observations converted into Fahrenheit degrees, which are claimed to be precise in every instance, and all computations are with the strictest regard to his own observations.

Pp. 46–52 give tables for each degree of Fahrenheit. Pp. 53–66, tables of Hyperbolical Logarithms to Five Places, Notes as to Clearance Included, as Changing Ratio of Expansion. Pp. 67–70, Engine Constants, which are computed entirely by the author, beginning with the diameter of the piston, the area, the logarithm of the area; the constant for one foot; the constant for 100 feet; the constant for 1,000 feet; the logarithm of 1,000 feet. This table is said to have been calculated with the best table of logarithms, and, is, so far as I have recalculated it, from personal observation, more accurate than similar tables in some books that have long been considered standard. Pp. 71–75 give tables of the Pressure, Volume and Density of Saturated Steam, with nine columns of useful data, and these are followed by Regnault's results at the Paris observatory (pp. 76–78).

Pp. 80–81 give Mean Pressure (absolute) Multipliers for any pressure in each one-thousandth of the stroke. Pp. 82–85, the last table of the book, give data from Rankine, computed by the author, of steam used expansively.

The author explains that after careful investigation he has decided upon following Regnault as the most reliable authority in tables for pressure, temperature, volume and density of dry saturated steam, holding to 26·36 cubic feet to the pound, in preference to 26·57, as given by Wood and other authorities.

Many of these tables will be found useful in reference to matters other than those connected directly with the steam engine, particularly the tables of weight of water in regard to its temperature.

The size of the volume, 10 inches by 6½ inches, is handy, and the clearness of the type makes its use for reference convenient and agreeable. The margin of each table is sufficiently wide to permit the same kind of marginal index to be applied as that which has proved so convenient in Foley & Pray's "Engineers' Reference Book," which system might well have been added to this volume. C. S.

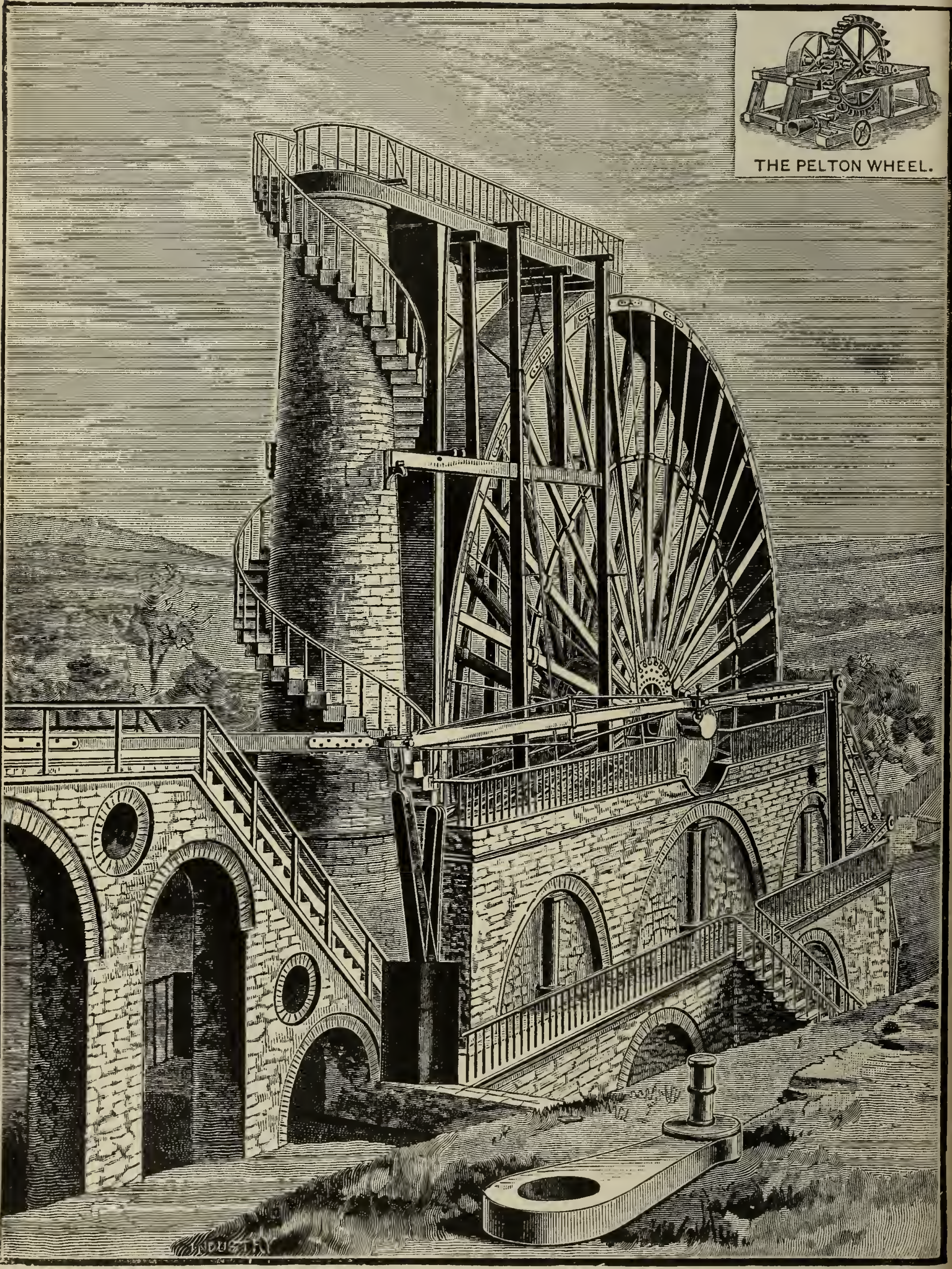


FIG. 6.—THE OVERSHOT WHEEL AT LAXEY, ISLE OF MAN.

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXL. SEPTEMBER, 1895. NO. 3

THE PELTON WATER WHEEL.

(Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Lester A. Pelton.)

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, November 2, 1894.

The Franklin Institute of the State of Pennsylvania, for the promotion of the mechanic arts, acting through its Committee on Science and the Arts, investigating the Pelton water wheel, reports, that:

The Pelton water wheel is what may be termed an impulse reaction wheel, the power of which is derived from the pressure afforded by a head of water, supplied by a line of pipe, discharged upon it through a small nozzle, the size of said nozzle being proportioned to the amount and head of water available, and to the power required. The manner of utilizing this pressure is the distinguishing feature of the invention and the secret of its success.

The plane of the wheel is vertical, turning upon a horizontal axis, the bearings of which are mounted and fixed upon a wooden or metal frame, to which also the nozzle is attached, making the machine, as a whole, self-contained. The bearings are accessible at all times for examination and lubrication, and are easily protected from water and grit.

Over the wheel, but not touching it anywhere, is placed a cover for withholding the sling of the water from the wheel, and directing it vertically downward to the tail-race, whence all waste is carried away.

It has a number of buckets or cups, like *Fig. 1*, fastened to its periphery, each provided with a wedge dividing the jet (which is applied tangentially) into two parts, one turning to the right, the other to the left (shown in section in *Fig. 2*), the direction of both being almost completely reversed before the water leaves the bucket. To facilitate the escape of the spent water and to utilize all of the head, the stream is usually applied to the lower side of the wheel. The object in this, as in other wheels, is to receive the water without shock, to discharge it without velocity, and to apply the energy thus liberated to turning the wheel in the most efficient manner.

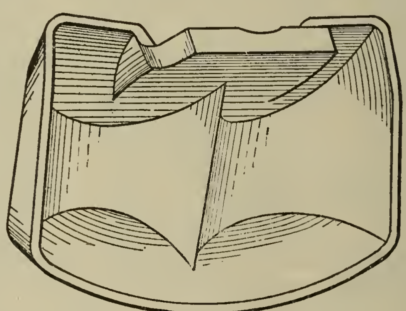


FIG. 1.

The Pelton wheel was developed in the mountainous regions of California, and was tested and improved by men who knew its value. It was eminently suited to the conditions existing in such localities, where water was to be had under high pressures and where portability of the wheel was

essential. In the early days of mining, when roads, or rather trails, were few and rough, much of the machinery had to be transported on the backs of mules and burros, which animals were capable of carrying a load of about three hundred pounds. Lightness, was, therefore, a most important feature; and that this was realized to an important degree in the Pelton construction may be seen by the following examples of wheels working under high pressures.

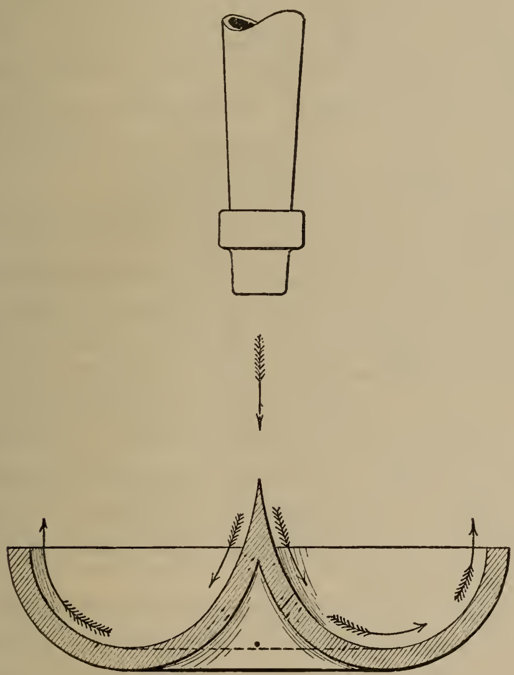


FIG. 2.

In the Comstock mines at Virginia City, Nevada, are located six wheels, each weighing 220 pounds, developing 125 horse-power each with a stream five-eighth inch diameter, and a head of 1,680 feet. They are forty inches in diameter, are made of phosphor-bronze, and run at a speed of 900 revolutions per minute.

Probably the most extraordinary water-power installation, so far as head is concerned, that can be referred to, is

that made some two years ago in one of the famous Comstock mines, at Virginia City, Nevada.

This consisted of a thirty-six inch Pelton wheel (*Fig. 3*), made of a solid steel disk, with phosphor-bronze buckets securely riveted to the rim. It is located at the Sutro Tunnel level of the California and Consolidated Virginia shaft, 1,640 feet below the surface. In addition to the head afforded by the depth of the shaft, the pipe is connected to the line of the Gold Hill Water Company, which carries a head of 460 feet, giving the wheel a vertical head of 2,100 feet, equivalent to a pressure of 911 pounds. The water, after passing over the wheel, is carried out through the tunnel, four miles in length. The wheel runs at 1,150 revolutions, which gives it a peripheral velocity of 10,804 feet per minute, or about 120 miles per hour.

The construction of the wheel amply provides for the centrifugal strain given by the velocity of the water, running without load, when it would attain the enormous speed of 21,608 feet per minute, equal to about 240 miles per hour. A nozzle tip one-half inch in diameter gives under above conditions 100 horse-power. Every miner's inch of water, equal to a flow of 1·6 cubic feet per minute, gives five horse-power, while one horse-power is given for every two pounds of metal in the wheel. It is only by comparison that an idea can be obtained of the height of a column of water due to such pressure. It is more than four times as high as the Washington Monument.

At the plant of the Roaring Fork Electric Light and Power Company, Aspen, Col., there are eight Pelton wheels twenty-four inches in diameter, each weighing ninety pounds, and capable of developing 175 horse-power, or about two horse-power for each pound of metal in the wheel. The speed is 1,000 revolutions per minute, and the head 820 feet. The complete outfit, including shaft, boxes, pulleys, gate and nozzle, weighs four and one-half pounds per horse-power developed.

The extreme simplicity of these wheels renders them strong and durable, not liable to get out of order, and enables them to be run with a minimum of wear. Breakage

seldom occurs; the wear is confined to the large shaft bearings and to the vane surfaces over which the water passes. There are no running water joints to preserve, and the nozzle is of the simplest and most efficient form, the cylindrical jet being commonly used. The path of the water in the bucket is short, reducing friction to a minimum. If the water carries abrasive materials, the effect is sometimes seen on the wetted surfaces, but the wear is slight, and never detrimental to efficiency. Then again, all the wheels above two feet in diameter have the buckets bolted on, so that one or more may be easily and quickly replaced without disturbing the installation. This is an advantage which is everywhere appreciated, especially in localities far removed from industrial centres.

It has been found that in very cold weather turbines have been interfered with by the formation of ice, which clogs the joints of waterways. The 24-inch Pelton wheels at Aspen, Col., before mentioned, are at an altitude of nearly 8,000 feet; but notwithstanding the consequent severe winters, they are running without interruption, it being only necessary to keep them in motion. The water cannot remain in the wheels, and therefore does not freeze.

The shafts of these wheels are horizontal, facilitating the driving of machinery, often enabling direct shaft connections to be made, as in the case of many electrical plants. Knowing the head or pressure, the diameter of the wheel can often be made to give the speed required. Such applications are easily made, but are not possible in all cases, as where a high speed is wanted from a low head and a large quantity of water.

The tendency of modern machine practice is to introduce direct connections between the motor and the machine to be driven, thus simplifying the parts, reducing first cost and maintenance, and economizing space. The construction of the Pelton wheel enables this to be done in all cases where the head, which controls the speed of the buckets, is so related to the rotative speed as to give a wheel of reasonable dimensions (see *Fig. 4*). The minimum diameter depends, to a certain extent, upon the quantity of water to

be used; if this is large, it may be necessary to use more than one jet on the wheel, or to use two or more wheels on the same shaft, to obtain the required speed. The application of several jets to a wheel does not impair the efficiency when it is carried out according to well-known rules (see *Fig. 5*).

A consideration of the relative cost of installing a free jet wheel and another kind of wheel of equal power will convince any one of the advantage in favor of the former. The cases and foundations are light and simple, there are no expensive penstocks or draft-tubes, no inconvenient means of transmission, no heavy stonework.

Those who have been on the Isle of Man will remember the large overshot wheel at Laxey, with its massive work in the shape of foundations, towers, etc. (see *Fig. 6*). The wheel is seventy-two feet six inches in diameter, and develops about 150 horse-power, the power being used for pumping purposes in a lead mine.

A Pelton wheel, six feet in diameter, with this head, will develop the same power with much less water and with a great saving in first cost of wheel and installation, the proportion being probably fifty to one in favor of the Pelton wheel.

Hamilton Smith, Jr., stated before the American Institute of Mining Engineers, in 1884, that, to his knowledge, about 800 turbines had been taken out in California on account of wear and consequent low efficiency. Turbines have a distinctive advantage under very low heads, because of the large quantity of water which they can utilize, but under high pressures the speed becomes excessive and destructive. A free jet or tangential wheel may run to the limit fixed by the strength of the material without injury, there being no wear except in the bearings. The point at which it becomes advisable to use turbines depends, to some extent, on conditions other than pressure, and would have to be determined from the full particulars of the case.

The construction of these wheels indicates that a high efficiency may be obtained when running with a full or re-

duced water supply, and such has been found to be the case. Buckets are designed for a maximum diameter of stream, without reference to the head, but the only objection to using a much smaller stream would be the disproportion of weights and friction surfaces, an objection which is of very little practical importance. This method is adopted when the quantity of water varies, the minimum stream being often only twenty-five per cent. of the maximum. This can be done with no appreciable loss of efficiency, in strong contrast with the turbine, with its variation of twenty per cent., more or less, under varying gates.

In many cases of use in the mountains there is no need for governing devices; on stamp mills, for instance, when such are necessary, the method used will depend upon the water supply. If a liberal use of water is allowable, a nozzle is used having a ball-and-socket joint, which permits the stream to be partly or entirely deflected below the buckets (see *Fig.* 7). It is called a "deflecting" nozzle, and in its general features resembles the apparatus used in hydraulic mining.

The centrifugal friction governor has been used to a very great extent, the balls acting on a double-geared bevel friction wheel, which opens or closes a butterfly valve (see *Fig.* 8).

When a constant speed can be obtained from a source outside of the wheel itself, as from an independent motor, the differential governor is available (see *Fig.* 9). This consists of four mitre gear wheels in mesh, each forming the side of a square; two opposite gears being loose on the shaft and driven in opposite directions by pulleys and belts; the remaining two running free on studs, which project from a hub fastened to the same shaft. So long as the pulleys run at the same speed there will be a simple rotation of the gears on their axes; but if one runs faster than the other, the gears on the studs will be revolved bodily around the shaft. This motion, which is very sensitive, is made to open or close a butterfly valve in the service pipe. Safety stops are provided at full open and full shut, to prevent the governor from binding the valve and

possibly breaking something. This method is advantageous in electric lighting, where there is a demand for close governing.

The old method of mounting these wheels has been criticised by some, but it should be remembered that the wheel and its accessories have been developed in the mountains, and have naturally been influenced by the surroundings and conditions of erection and use. The transportation of heavy iron cases on the backs of animals and over bad roads was a serious question, so recourse was had to wooden frames usually constructed on the spot, as shown in *Fig. 10*. They were made of heavy timber, bolted together and boxed in so as to be water-tight. The shaft and nozzle had ample support, and so far as use was concerned, they fulfilled every requirement. In later years iron has come into use very extensively, either cast or in sheets riveted together, making a machine ready for the application of the water. These remarks apply only to the larger wheels, as the small ones have, from the first, been mounted in well-designed cases (see *Fig. 4*, which shows a twin motor with the cover removed).

Nothing contributes so much to the prosperity of mining and manufacturing as cheap power. Scores of the largest producing and most profitable mines on the Pacific Coast could not be worked to-day but for this, as most of our heaviest mining operations are based upon handling a large amount of low-grade ore in a most economical way. Another fact, indicating the change wrought by the introduction of these wheels, is the high price that low-grade mines are commanding, when so situated that water-power can be availed of; these mines, a few years ago, could hardly be given away.

Where the power developed by the wheel cannot be applied directly to the machinery to be operated, electrical transmission can cover the intermediate space, and so in time these easily established links will connect many of the great industrial establishments with these water-powers, now by this wheel made economically available.

That this result has already been accomplished to a much

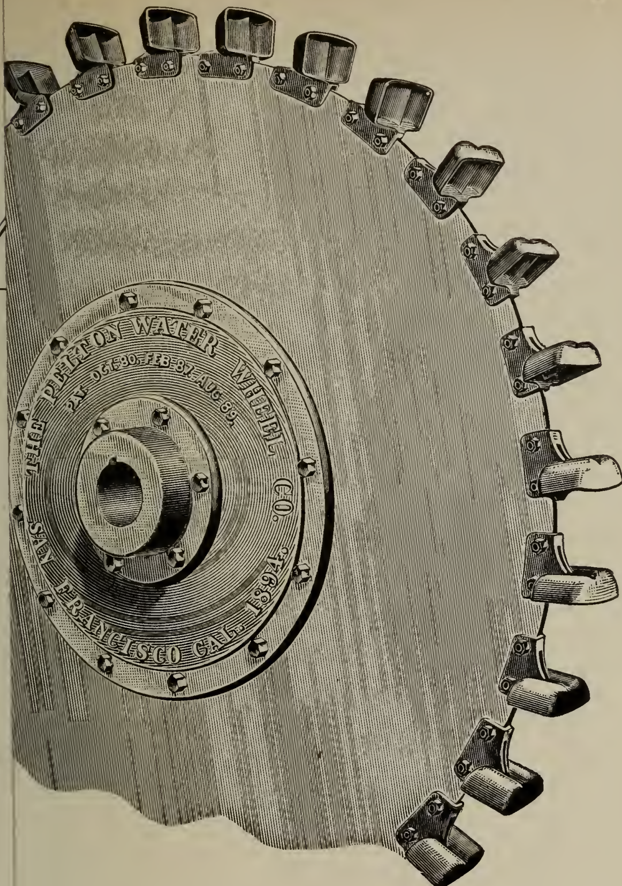
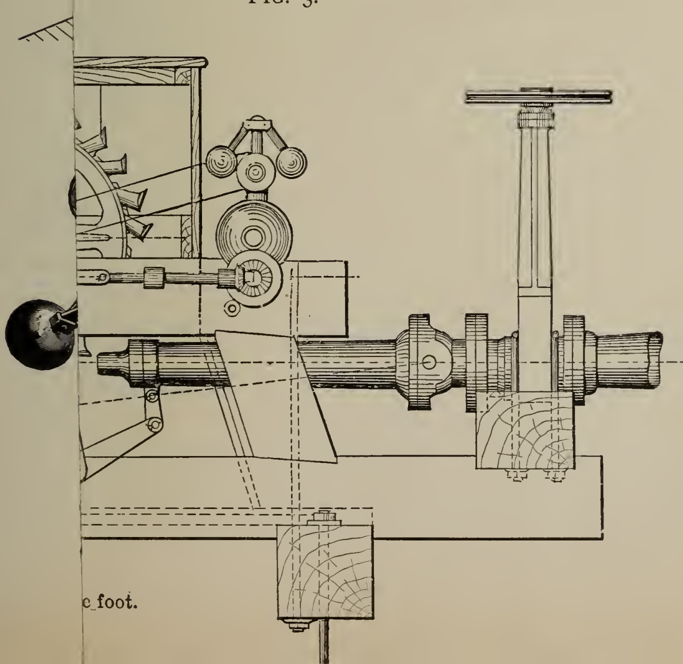


FIG. 3.

FIG. 10.



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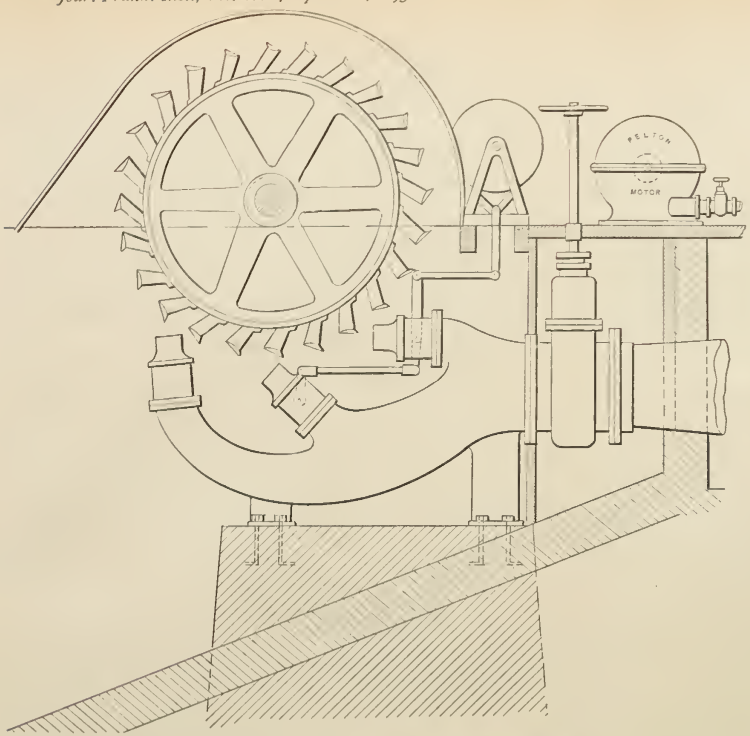

PELTON
MOTOR

FIG. 5.

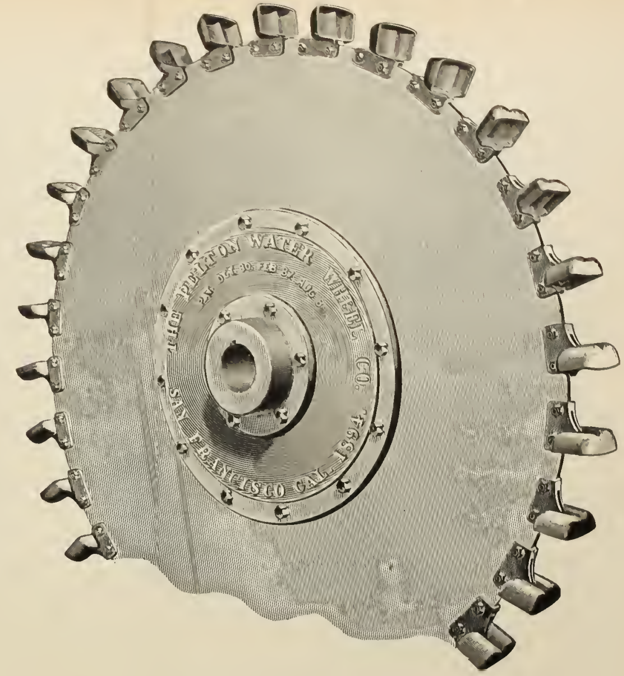
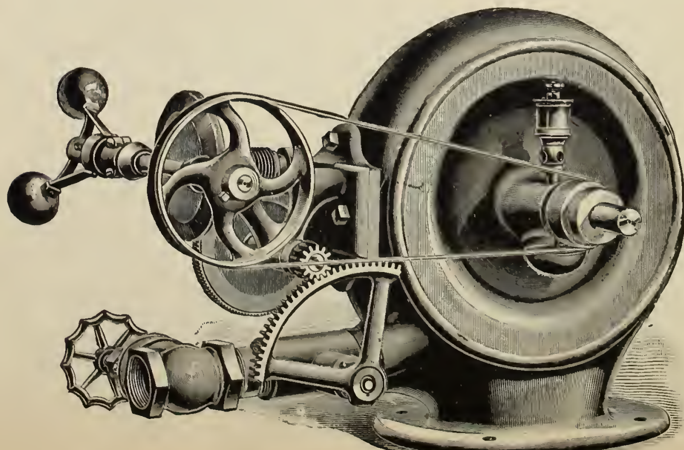
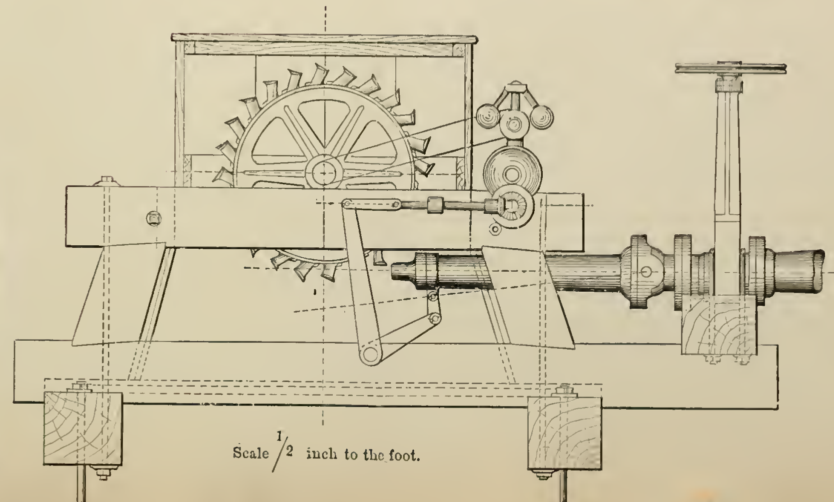

THE PELTON WATER WHEEL CO.
SAN FRANCISCO CAL. 1894.

FIG. 3.




Scale $^1/_2$ inch to the foot.

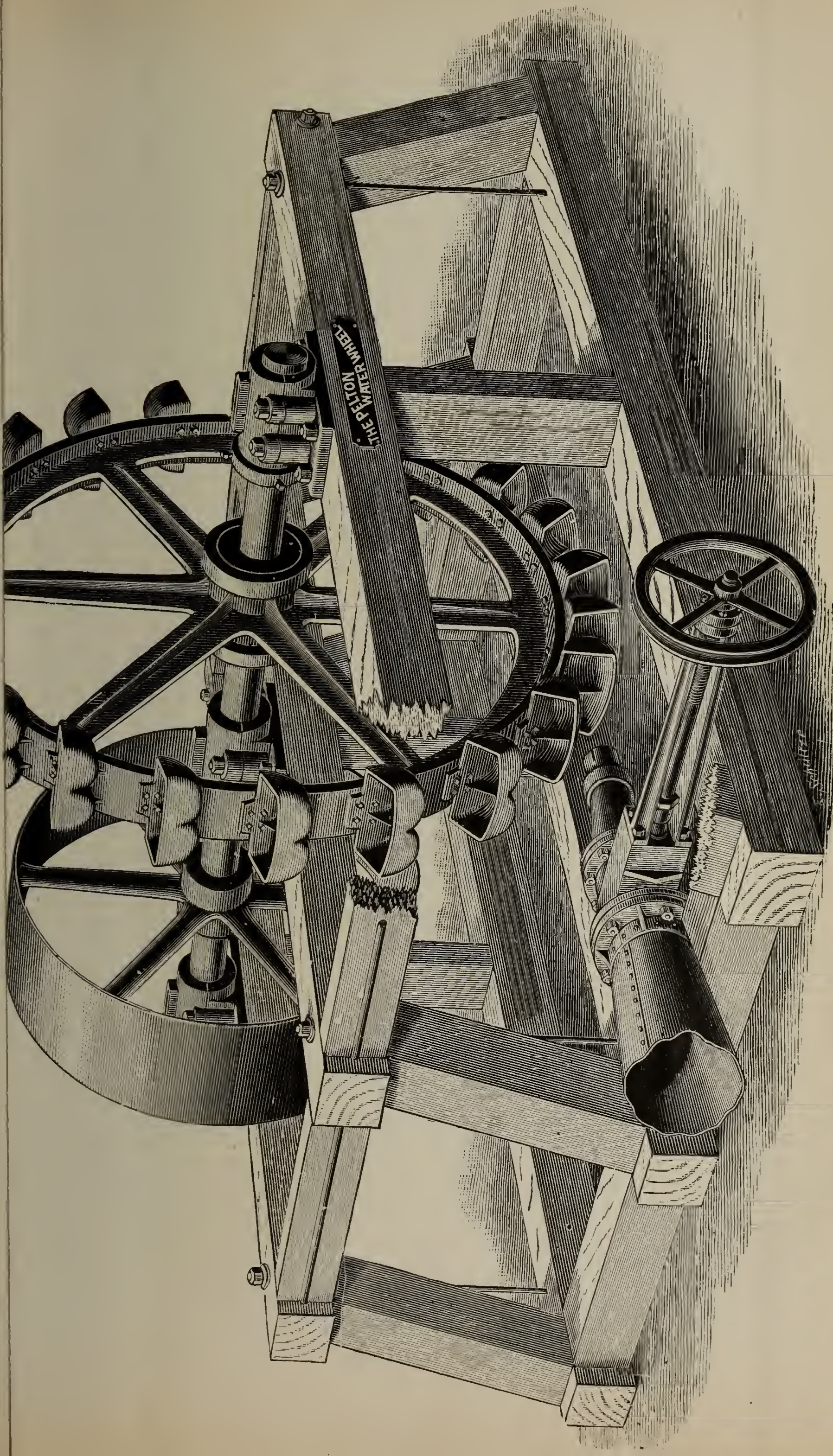


Fig. 10.

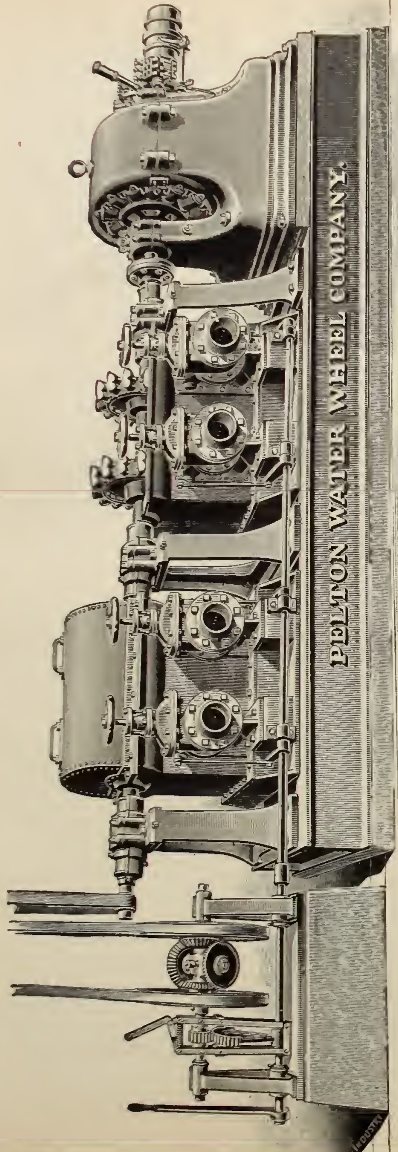


Fig. 4.

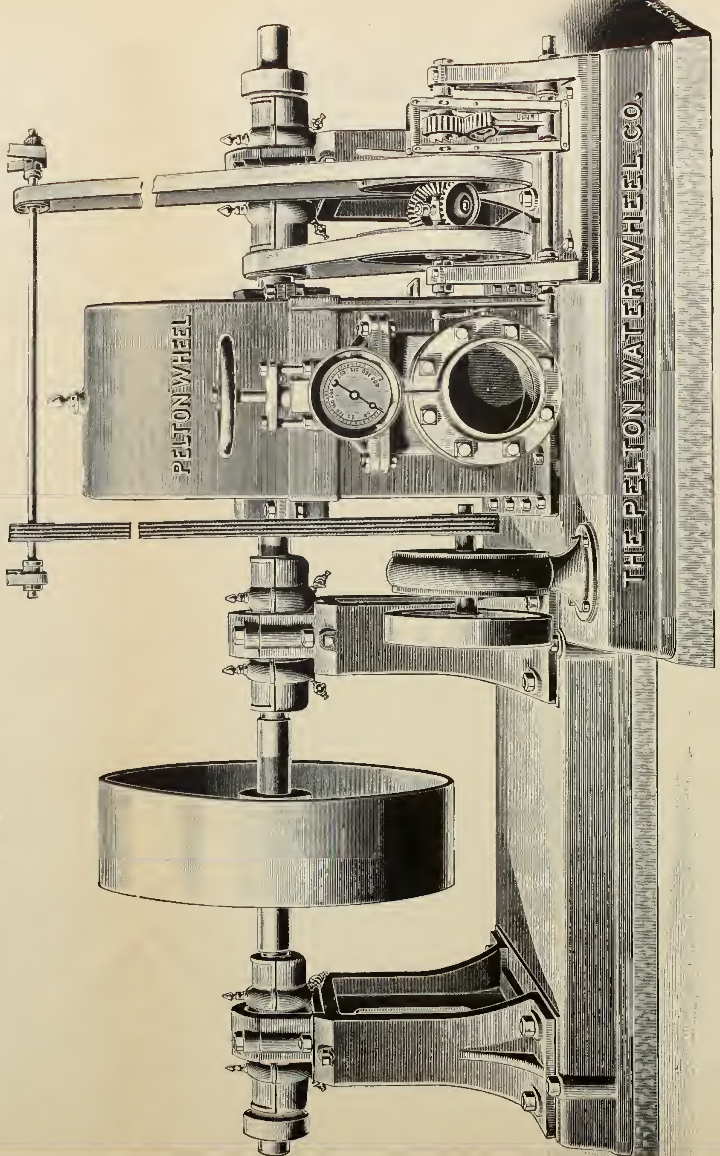


Fig. 9.

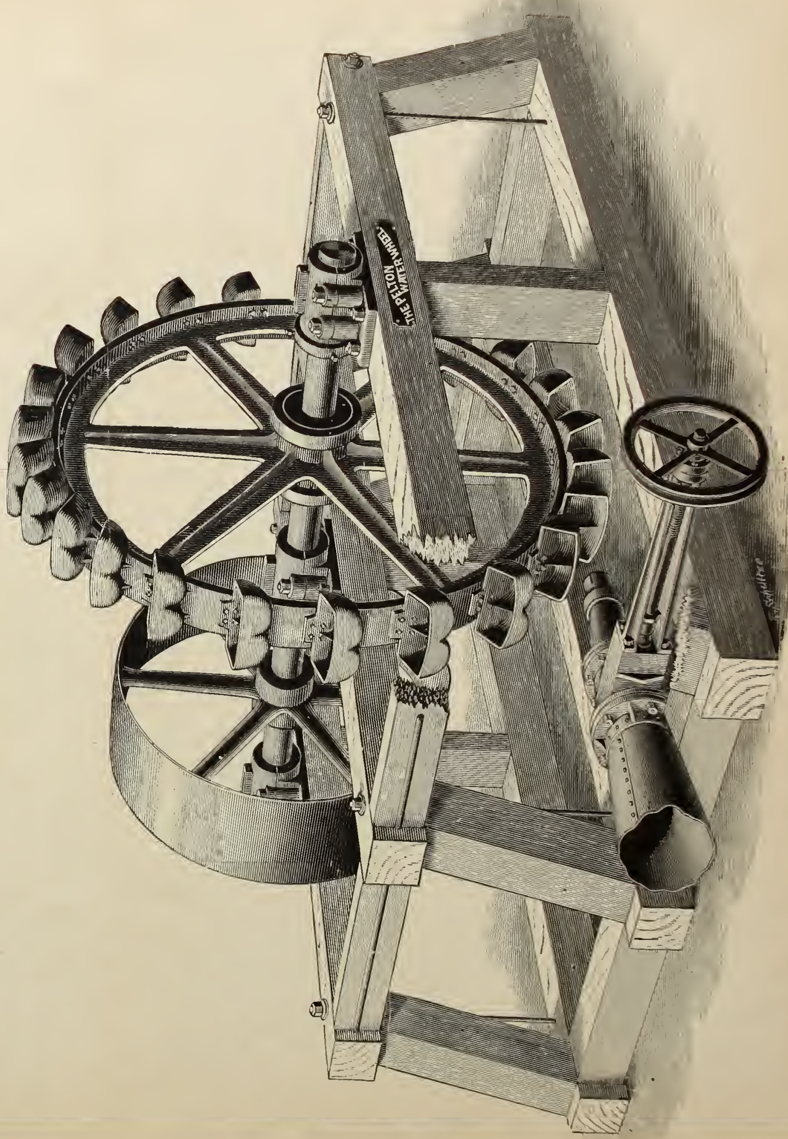


Fig. 10.

greater degree than was ever thought possible, is evidenced by the hundreds of mining and other enterprises on the Pacific Coast, as well as in many other parts of the world, that are using this motor profitably.

The remarkable efficiency of the Pelton wheel is a surprise to all who see it in operation for the first time. That a wheel so small as almost to escape observation should be capable of driving the large amount of machinery that is often attached to it, is a perpetual wonder, even to those long accustomed to its use. Nothing but a humming sound is heard; and a little rivulet flowing from it, scarcely more than a thirsty horse would drink, is all that is seen.

Its absolute simplicity of construction, as well as its perfection in mechanical detail, afford the greatest possible security against irregularity in running or necessity of repair. Many have now been in constant use for at least ten years, with little stoppage or wear. In fact, no wear is possible, except with muddy or gritty water. In such case the buckets may need replacing once in two or three years. This, however, involves but little time and small cost. The buckets being open, with a free discharge, are never obstructed by leaves, roots or other foreign matter.

These wheels are made in sizes from four inches in diameter, and weighing, with case, twenty pounds, for driving sewing machines, dental apparatus, and the like, to wheels of five, six, eight, ten and in some cases even twenty feet in diameter. Wheels of such large diameter are not for the purpose of increase of power, but to reduce speed so as to make a direct connection to the shafts of the machinery they are to operate as in the case of pumps, compressors, etc. By applying three, four or five streams to a wheel of ten to fifteen feet in diameter, from 3,000 to 5,000 horse-power can be obtained from a single wheel under a head of 150 feet. This illustrates the extreme flexibility of the system and its application to varying conditions, units of power, speed, etc.

In considering the conditions necessary to a high efficiency in the jet wheel, it will be found that the main conditions are as follows:

(1) The jet should enter the bucket without shock and flow over easy curves until its direction is reversed:

(2) The surface over which the water passes should be small to reduce skin friction:

(3) The speed of the wheel should be such that the water will leave the bucket without velocity.

Prof. Unwin, in an address to the Institution of Civil Engineers, about 1885, stated that:

"About twenty years ago there was introduced a form of impact wheel called the 'Hurdy-Gurdy.' (See *Fig. 11*,

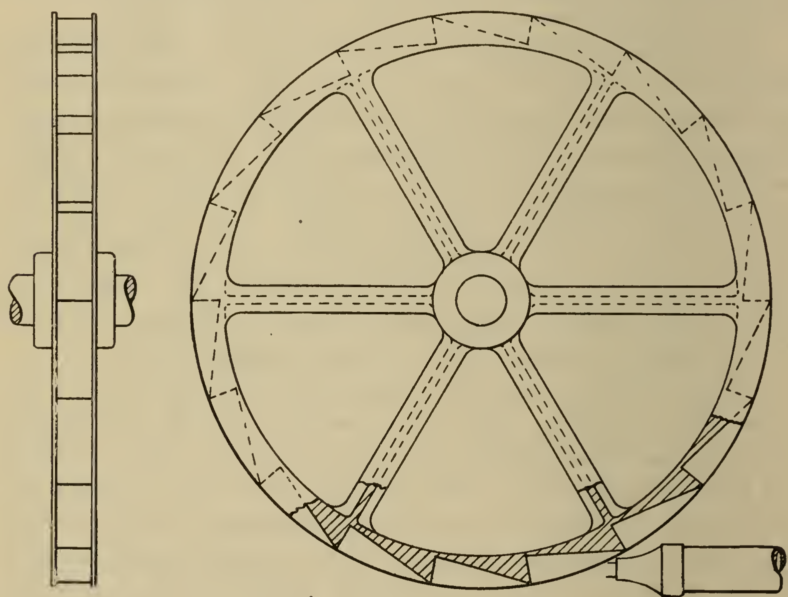


FIG. 11.

which shows a side and front view of a simple form of this wheel, having flat radial vanes. Part of one of the side plates has been cut away, to show more clearly the manner in which the jet of water is received, while the nozzle shows the location of the stream.) It consisted of a wheel of considerable diameter, with a series of cast-iron floats, four to six inches wide on the face. A jet of water was allowed to strike the vanes normally. Theory shows that in this case the wheel should run at half the speed of the

jet, and that the efficiency, even apart from the friction, could not exceed fifty per cent. Practical experience also shows that the wheel should have half the velocity of the jet, and the efficiency was found, by experiment, to be forty per cent. In spite of the low efficiency, such wheels seem to have been useful, partly because they were cheap and free from liability to accident, but mainly probably because by choice of diameter of wheel any convenient speed of rotation can be obtained.

"It is easy to see that the efficiency could be improved by substituting cups for flat floats, and this is what has actually been done. The favorite now is a wheel termed the Pelton wheel, the floats of which are simply cups which

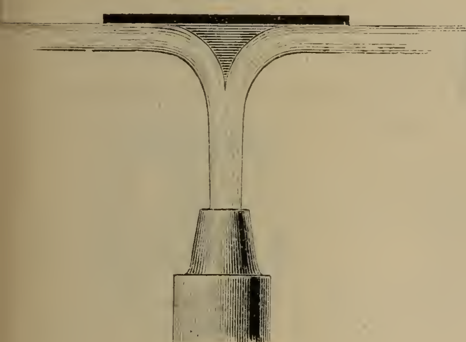


FIG. 12.

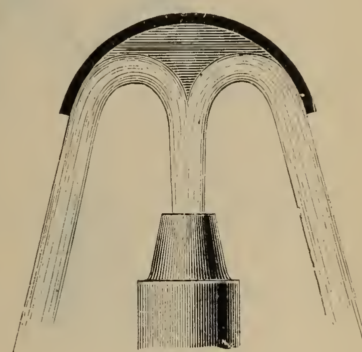


FIG. 13.

deviate the water backwards. I see no reason why, with a very high fall, an efficiency of eighty per cent., at all events, should not be reached."

Professor Merriman says, in discussing the "Energy of a Jet:" "The amount of work which is realized when a jet strikes a moving surface, like the vane of a water motor, depends upon a number of circumstances, and it is the constant aim of inventors so to arrange the conditions that the actual work may be as near to the theoretic energy as possible. Values expressing the efficiency, greater than 0·90, have been obtained."

Statements such as these, coming from the best authorities, give encouragement to those who handle the practical

side of these problems, by showing that high efficiencies are possible.

Flat Vanes.—Fig. 12 shows the action of a jet of water striking a flat plate at right angles. It will be seen that the water divides and shows a tendency to form a wedge of still water; this is what may be termed "dead" water, that is, water which has lost its impelling force. In a wheel having this form of vane, there is a tendency to form such a wedge on each vane at every revolution; there can be no smooth flowing of the stream, but a continual turbulence, resulting in a loss of energy, and the amount of this will be greater than the loss of part of the energy contained in the water represented by the wedges. It will be seen, also, that the

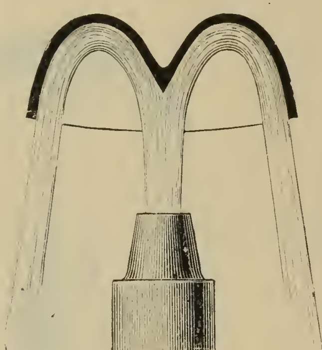


FIG. 14.

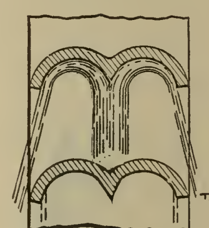


FIG. 15.

direction of discharge precludes a complete stoppage of the water, the highest theoretical efficiency being fifty per cent., excluding losses from friction, turbulence, etc.

Curved Vanes, No Wedges.—In the simple curved buckets shown in *Fig. 13* will be found the same condition as to wedge formation as was shown on the flat plate, the amount of water so perverted being even greater. There is, however, a reversal of the stream which allows it to be almost completely checked. This is an important advantage, as may be seen in a comparison of the efficiencies obtained.

Curved Bucket with Wedge.—Fig. 14 shows a third form, in which the wedge has been made a part of the bucket itself, thus avoiding the loss due to the water wedge and to turbulence. *Impact* has been reduced to a minimum, and the

bucket forms part of an *impulse* wheel. This is the Pelton, which has shown a higher efficiency than any other jet wheel, and which is now replacing the older forms.

In wheels having flat radial vanes or buckets, and a tangential application of the stream, the angle of impingement varies as the vanes pass through the jet, but there is at all times an *impact* resulting in a loss. In contrast with this is the *impulse* wheel, in which the water enters the vanes or buckets without shock, and is led in the proper path, there being no coercion of the water, but a smooth, regular flow. In the *impact* wheel there is a *blow struck*, while in the *impulse* there is a push.

It will be seen that the impact wheel or "Hurdy-Gurdy" conforms to only one of the principal requirements for efficiency, namely, that of a short path on the vane; the simple curved bucket without wedge introduces two of those conditions and part of the other. The double curved or wedged bucket embodies all of them.

Some tests by Ross E. Browne, at the University of California in 1883, show the comparative value of the different buckets or vanes.

Under a head of fifty feet, and with a three-eighth inch nozzle, the following efficiencies were obtained:

	Per Cent.
Hurdy-Gurdy	40·4
Bucket without wedge	65·6
Bucket with wedge	82·5

In explanation of the result obtained by reversing the stream, let the speed of the jet be ten feet per second, then the bucket speed will be five feet per second. It follows that the jet speed in relation to the bucket will be the difference, or five feet per second. When the water is reversed, the jet movement in the bucket is in one direction, while the bucket travels in the opposite direction at the same rate, the result being that the water drops from the wheel without velocity. It is evident that at no speed will it be possible to completely check the water in the flat vane wheel.

It is not possible to completely reverse the stream even in the double curved bucket, the reason of which is shown in *Fig. 15*. Something must be sacrificed in this direction in order that the water may clear the bucket which follows. The angle of deviation will depend upon the distance between adjacent buckets, but in no case should the loss from this cause exceed one per cent.

To make such tests of this wheel as would be convincing and satisfactory, the committee charged with this investigation found to be impracticable. In lieu thereof, the committee has found it necessary to rely upon the corroborative results of tests made by men esteemed by the committee as fully competent to do such work.

In the tests of this wheel made by Mr. Ross E. Browne at the University of California, "the diameter of the wheel was fifteen inches, the width of the bucket 1·5 inch, and the efficiencies shown under fifty-foot head were as follows:

"With a seven-sixteenth-inch nozzle, 82·6 per cent.; with a three-eighth-inch nozzle, 82·5 per cent. The efficiency was determined under as low a head as eight feet, still showing 73 per cent. It is proper to state that the wheel with which the above tests were made was constructed in the workshop of the University, and did not conform wholly to the manufacturer's standard. The size of the bucket was too small to do full justice to the wheel, owing to the difficulty of shaping the curves accurately. It is claimed that tests with larger wheels have given higher efficiencies, and I have no reason for doubting the claim.

"I do not hesitate to express the following opinions regarding the Pelton wheel operated by circular jets:

"(1) It will give a high efficiency under a wide range of heads, say from twenty feet upward:

"(2) It will be equally efficient whether operated by very small or very large nozzles, provided the proper ratio is maintained between the diameter of nozzle and size of bucket, etc.:

"(3) Its general simplicity of construction is a matter of great advantage in its application as a motor. In designing a plant, the size or number of wheels can be more readily

adapted to the requirements of speed, of shafting, and distribution of power, without sacrifice of efficiency or entailment of extravagant cost. It becomes practicable to make more direct applications of the power, frequently enabling the avoidance of counter-shafting, etc.:

"(4) It meets the requirements of a high-head wheel much more efficiently than do the common forms of turbines. It is evidently far better adapted to high heads than the closed or full-running turbine.

"Closed turbines are distinctly *low-head* wheels, and are not efficient motors under high heads. A high velocity of the enclosed wheel of a full running turbine causes great agitation and turbulence of the confined water, and it is readily apparent that there occur extravagant losses by impact. The superior efficiency of the Pelton, as a high-head motor, is due to the high efficiency of the circular nozzle, the smooth and rapid deflection of the water in passing through the open bucket, and the small aggregate amount of wetted surface in the buckets."

A test was made in the Mechanical Department of the University of Michigan, under the direction of Prof. M. E. Cooley.

A twelve-inch wheel was used, the size of the nozzle one-quarter inch to one-half inch, the efficiency obtained was eighty per cent.

These experiments may be regarded as disinterested ones, being made wholly from a scientific standpoint, while the high character of the institutions mentioned afford assurance of accuracy in all details as well as in conclusions.

The adoption of this wheel by a great number of companies is the best evidence of superiority. Referring to one of the manufacturer's printed lists, we find that 840 companies are using these wheels, many of them running from ten to fifteen wheels under heads varying from 18 feet to 2,100 feet.

Notes Regarding the Operation of the Chollar Plant.—This station is located at the Sutro Tunnel level of the Chollar

shaft, and consists of six Pelton wheels, forty inches diameter, connected direct to electric generators, the power from which is carried by wire to the surface and operates the California Mill. The wheels are running under a vertical head of 1,640 feet at 900 revolutions, each wheel giving off 125 horse-power, with a nozzle five-eighths of an inch in diameter.

The following statement from the superintendent of the Chollar Mining Company, referring to the electrical plant above described, is given for the purpose of showing the practicability of operating electric generators underground, and also the reliability of a power plant running under such extraordinary conditions:

"As regards the operation of water wheels on the shafts of the dynamos, there is, in my opinion, no better way of running them where the head will admit of such a direct connection. The Pelton wheels attached to the generators in the station at the Sutro Tunnel level of our shaft, have now been in operation for some three years without giving any trouble, and with very little expense in the way of repairs, and they have given entire satisfaction as regards efficiency, regulation and general reliability. As to running generators underground, I consider it quite as feasible as operating them on the surface; and if I were going to run another plant under similar conditions, I should use Pelton wheels attached to the shafts of the generators, as in the present case, believing it to be the most efficient and economical method of producing power.

"Many of these wheels have been in constant service for several years, with no trouble whatever, and with practically no expense in the way of repair. Though running under such extraordinary conditions they are still in perfect order, and good for an indefinite period of service. The Pelton wheel is equally adapted to moderately low heads, say from twenty feet upwards, it being in any case simply a question of adaptation of nozzles and buckets to water available, head and power requirement."

It may be of interest to refer briefly to some predecessors of the wheel under consideration.

The Roman architect and engineer, Vitruvius, about 14 B. C., figures and describes water mills, in which the millstones are turned by a current-driven wheel, shown at *C* in *Fig. 16*, the same having flat, radial vanes, against which the water acts in its flow down-stream. Upon the horizontal axis of this wheel is a toothed *tympanum B*, geared into and

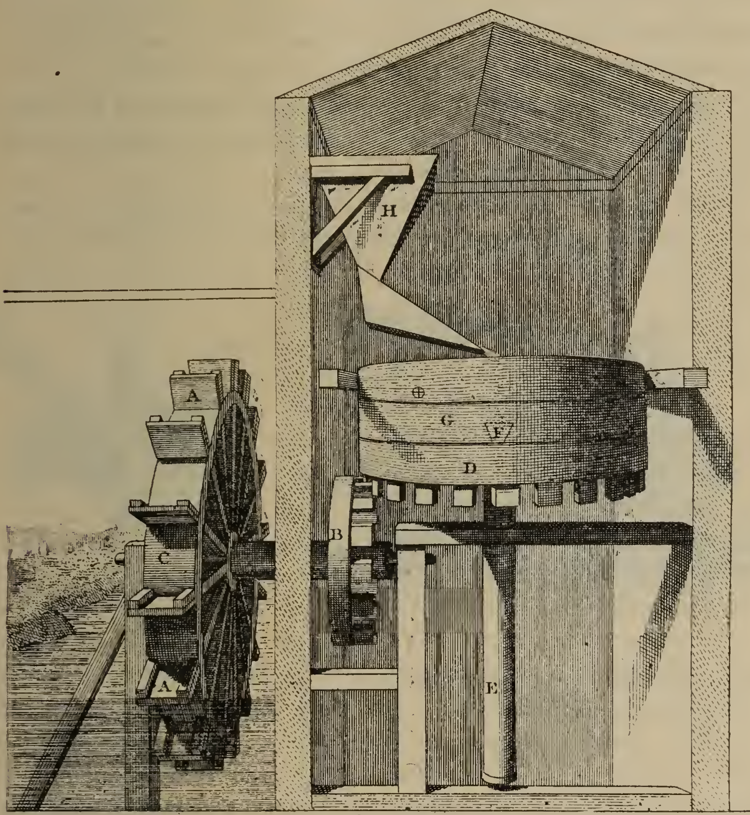


FIG. 16.

set to turn the larger horizontal *tympanum D*, secured to the vertical shaft *E*, "having at its upper end an iron dove-tail *F*, which is inserted in the millstone *G;* thus the teeth of the tympanum *B*, that is included on the axis, impelling the teeth of the horizontal tympanum *D*, cause the rotation of the millstone to which the suspended hopper *H* furnishes the grain, and by the same rotation the meal is ejected."

Later on, when Rome was besieged (A. D. 537), the supply of water from the aqueducts which fed the canals being cut off, Belisarius placed boats on the Tiber, and upon them erected mills.

These consisted of two boats moored in the stream, say two feet apart, and across this space, from boat to boat, a horizontal shaft was placed in bearings, with the water wheel upon the central part, its buckets or vanes dipping into the stream, the force of the current turning it, and, through proper gearing, turning the millstones for grinding the corn. This episode may be considered as marking the origin of "floating mills."

"In the year 1629, Giovanni Branca, of the Italian town of Loretto, described, in a work published in Rome, a num-

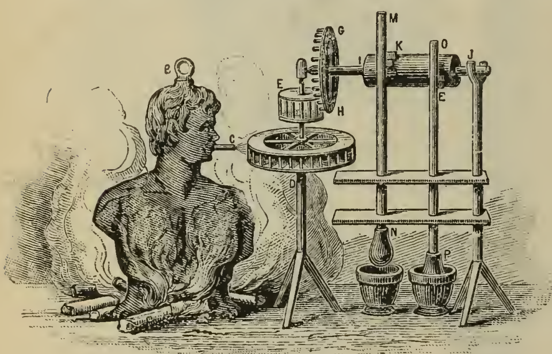


FIG. 17.

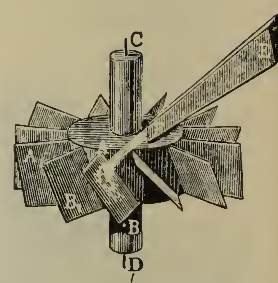


FIG. 18.

ber of ingenious mechanical contrivances, among which was a steam engine, shown in *Fig. 17*, in which the steam issuing from a boiler impinged upon the vanes of a horizontal wheel. This it was proposed to apply to many useful purposes." This is quoted simply as a good historical example of the invention and application of the jet to the propulsion of wheels.

One of the early forms of "impact" turbines is shown in *Fig. 18;* this is the simplest, but also the least efficient form of the impact wheel.

It consists of sixteen to twenty rectangular floats or vanes, *A B*, set upon the wheel so as to incline 50° to 70° to the horizon.

The water is laid on by a pyramidal trough, *E F*, inclined from 40° to 20°, so that the water impinges nearly at right angles to the floats.

Such wheels are employed for falls of from ten to twenty feet, when a great number of revolutions is desired, and when simplicity of construction is a greater desideratum than efficiency.

Wheels of this form are met with in all mountainous countries of Europe, and in the north of Africa, applied as mills for grinding corn. They are made from three to five feet in diameter, the buckets being about fifteen inches deep and eight to ten inches long. The efficiency of these wheels is half of the entire mechanical effect available.

In our list of early devices for obtaining the power of water, we must not overlook the familiar flutter wheel, the first contrivance of every boy who has hydraulic proclivities, and the readiest resort of the colonist, whereby he employs the dash of the neighboring mountain streams to turn the crank of his primitive saw-mill.

Economic considerations must in the future compel a wide use of the tangential jet wheels in this country. Heretofore the settlement of the country and its industries have been confined to flat lands, where the head of water available was suitable only for turbine wheels. Now that successful means of transmission exist, and various industries, especially mining, are extensively carried on in districts where the heads of water are great and the quantity small, jet wheels must take a prominent place among prime movers.

The committee charged with this work has been requested to consider the water wheel of Mr. Jearum Atkins. It will be sufficient here to repeat and analyse his claims, filed in the United States Patent Office, February 27, 1853, and which will enable us to understand the meaning and scope of what he proposed to do. His patent was not issued until August 10, 1875.

"*Claim 1.*—The mode of constructing water wheels with buckets placed longitudinally with the wheel's axis, with

semicircular water passages between them in combination with a water-trunk, so formed and proportioned as to cause the water to act continually upon all the buckets of the wheel.

"*Claim 2.*—The mode of constructing water wheels and apparatus connected therewith, so as to cause the water to impart its velocity, and consequently its power, to the wheels, by describing a half-rotary motion against semicircular-shaped buckets, formed and arranged in the manner set forth."

The words of this first claim, interpreted by the drawing and specification, clearly define semicircular waterways in the wheel, which are not only of even width and area throughout, but are also parallel with the axis of the wheel, and that the water supplied to a properly formed trunk surrounding the wheels acts upon all the buckets simultaneously.

Particular stress is placed upon the relative areas of the waterways to and through the wheel, the latter being made double the former, in order that the water in the wheel, as well as the wheel itself, may go at half the speed of the entering water; and since the motion of the water is reversed by the semicircular buckets, it leaves the wheel without velocity, and must therefore give up all its energy to the wheel.

The particular form of wheel disclosed by Mr. Atkins' first claim appears to have been new at that date, and he is entitled to credit accordingly, but as the investigating committee had no means of knowing the percentage of useful effect that was given by this wheel, by which the commercial value of a motor is determined, no estimate can be formed of the value of the Atkins wheel as compared with others in use.

It is to be regretted that Mr. Atkins was unable to prove, by test, the superiority of his wheel, and the most that the committee can do is to show what novelty there is in his proposition, in so far as his patent discloses his invention.

Considering this wheel, and the history of wheels, in detail, we find that the first current and jet wheels, and nearly all the under- and overshot and breast wheels, and

some of the turbines, built prior to the Atkins invention, have their buckets parallel to the axes of their wheels.

The following references also will be found pertinent to the case:

Poncelet, in 1827;
Madame de Girard, 1843;
Zuppinger, 1845;
De Canson, 1847.

Surrounding water trunks of various forms and capacities have been furnished to nearly all the turbines, from their first inception, in which special provision is made for the water to approach all the buckets freely and at once.

The records show semicircular waterways to be much less numerous than quarter-turn ways, which latter favor and secure the full force of impact, as well as the reactive effect of the water; in all these cases, however, the water makes a half-circle turn, being reversed in direction as it leaves the wheel, from the direction in which it enters.

This feature may be regarded as essential to the perfect waterway. It is embodied in all high-class wheels, and it is remarkable that this principle of action was conceived and formulated by that eminent mathematician, Euler, about the year 1750.

The Fontaine wheel, as at present constructed, is the nearest embodiment of his conception. This construction may be made clear by a few words: From a superposed enclosure the water enters curved guideways vertically, and is delivered horizontally and normally against all the curved wheel vanes at once, from which it finally issues in a horizontal direction.

This action of the water gives the wheel the full force of its impact as it enters, and of its reaction as it leaves the wheel, the water making a half-circle turn in its passage through the wheel.

It is fair to assume that every turbine wheel maker aims to secure this result; for by that act he catches and holds the water in the hollows of his wheel vanes till it gives up all its living force and then lets it drop speedless from the wheel.

The broadest interpretation that can be put upon Mr. Atkins' second claim would embody the idea of the half-circle turn made by the water in its passage through the wheel.

Poncelet, in the year 1827, was perhaps the first to call attention to and prove the loss of effect by the dash of the water against flat-faced vanes set normal to its course. For these he substituted curved forms, concave and tangent to the entering current, so that the water is continually running up concave inclines and running back again, permitting the water all the while to impart its energy to the wheel. Of this scheme it may be said: "The Poncelet float conspicuously demonstrates the essential importance of providing graduated entrances and avoiding shocks, concussions, or eddies in the water."

Here we have the fact well established that in order to secure higher results the water must both enter and leave the wheel in lines tangent to the course of the buckets.

In the wheel of James White, prior to the year 1822, will be found evidences of semicircular buckets and water inlets to them of lessened areas, all the water escaping in the same direction as that of the wheel; all the buckets are acted upon at once, and the floats are given "the most perfect form for receiving the utmost impulse from flowing water."

The wheel of Madame de Girard, Paris, 1843, has half-circle buckets, the water entering from beneath in a volute, and escaping all around outwardly.

In de Canson's French patent of 1847, with either horizontal or vertical shaft, "the water was directed against the lower blades from the interior by a simple pipe with a single orifice, opened more or less by a small vertical sluice." These buckets were quarter-circles, the jet striking them normally, the water escaping from the wheel tangentially.

Girard's wheel is upon a horizontal shaft, having two bearings, the water supplied through a nozzle covering a small part of the internal circumference of the ring of the buckets, the spent water escaping outwardly into an annular case surrounding the wheel.

The buckets are semicircular and parallel to the shaft. These wheels gave seventy-five to eighty per cent. of useful effect, a maximum of eighty-seven per cent. being recorded.

Even in the Whitelaw & Stirrat wheel, based upon the principle of the well-known Barker's mill (first observed by Bernoulli in 1730, and constructed by Segner in 1740), and which utilizes the reactive force only of the water, according to the best method of laying out the curves of the radiating arms, the central path of the water from the flume to its final escape into the atmosphere, is a semicircle.

In the United States patent of L. D. Goodwin, April 4, 1854, we find the following words in his claim: "The form and proportion of the buckets are specifically set forth, commencing in a true circle at a tangent to the outer periphery, and terminating in a straight line, fifteen degrees in length, at the inner curve, and in a tangent thereto." The water is admitted to all the buckets at once from a surrounding volute; the buckets are parallel to the axis of the wheel.

The subject is a complex one, presenting many forms of guideways and buckets, and numerous directions of water-flow to and from the wheels. Of course, all these are liable to cover one another in part and to present strong resemblance in detail, but nowhere do we find the exact counterpart of the Atkins wheel, nor any likeness to the Pelton.

In view of these earlier actualities of invention, surely Mr. Atkins can neither claim *broadly* the semicircular bucket for waterway through his wheel, nor the conception of the idea that the water should enter the wheel without shock and turbulence, and leave it without velocity or living force, describing a half-circle through the wheel to secure this result.

The semicircular bucket, as described by him, for the purposes named is, so far as we know, his invention, but no such construction exists in the Pelton wheel, nor does Mr. Pelton make claim for it, nor do we find on record even a hint of a divided bucket in any way resembling the Pelton type.

From all that has preceded, the conclusion is reached that the Pelton water wheel possesses all the advantages

of simplicity of construction, economy of installation and maintenance, adaptability to extreme heads of water, of transportability, of close and sensitive automatic regulation and of high speeds, which belong to other wheels of its class which have preceded it, but that in point of efficiency, it has excelled all others.

The Institute, therefore, deems the Pelton water wheel worthy of the Elliott Cresson Medal, and hereby awards the same to Lester A. Pelton, the inventor of this wheel.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 6, 1895.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
SAMUEL SARTAIN, *Chairman.*

APPENDIX.

[*Historical notes and data having reference to the foregoing report.*]

COMPILED AND EDITED BY JOHN H. COOPER, Chairman of the Sub-Committee.

The object of this Appendix is to present more in detail the data, dates and authorities relating to the curved buckets of water-wheels.

Since water-powers are coming to the front now for treatment, whatever light can be thrown upon the philosophy and construction of hydraulic motors must have immediate and commercial value.

A glance at German, French and English literature has revealed to the writer an elaborate and extended chain of valuable historic precedent, ot which a few links are here given, although in a somewhat disjointed array.

As early as the year 1744, Desaguliers said that a wheel of large diameter, as an overshot, may go with less water, if the water be applied to the wheel without any percussion.

Bernoulli recognized the loss of efficiency when the water leaves the wheel, and, soon after, Euler recognized the loss by impact. Borda, in his "Mémoire sur les Roues Hydrauliques," in 1767, announced the proposition in precise and general terms, whence he concluded that, to produce its total mechanical effect, the water serving as moving power must be brought onto the wheel with impulse, and quit it without velocity.

Atkins' second claim, embodying the idea of the water imparting velocity and power to wheels "by describing a half-rotary motion against semicircular buckets," * * * is a very sweeping one, and would cover broad ground if it were not limited to the construction specified.

The motion of water in a semicircle, while imparting power during its passage through a wheel, is as old as the first constructed turbine, which, so far as we have been able to raise the veil of history, dates with Euler's declaration of it in the year 1754.

An ideal elevation of the guides and buckets of an Eulerian wheel is given in *Fig. 19*. By following the water through the wheel, a half-circle motion will be indicated.* But the first introduction of Euler's idea to actual service was by Fontaine, prior to the year 1840. Our *Fig. 20*, taken from Dingler's *Polyt. Journal*, 1858, gives the forms of the waterways, which plainly appear to be well-nigh in conformity with a half-circle motion of the water while driving the wheel. Now we know that Euler was aware of the loss of efficiency by impact, and that a backward initial curving of the buckets was added later by many builders of wheels, thus securing the impulsive action of the water.

From "Belidor's Hydraulic Architecture," New Edition, by Navier, Paris, 1819 (see also "Encyclopédie des Sciences," Neufchatel, 1765), we transcribe as follows:

"In Provence and a considerable portion of the Dauphiny, the mills are of extreme simplicity of construction, consisting of only one horizontal

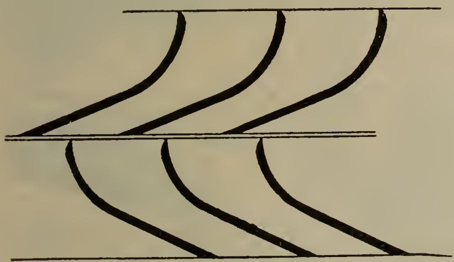


FIG. 19.

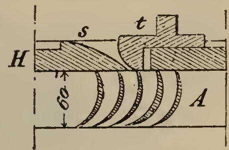


FIG. 20.

wheel, *D* (*Fig. 21*) from six to seven feet in diameter, of which the buckets are spoon-shaped in order to receive the stroke of the water which is delivered ordinarily through an inclined trough.

"The spindle *E*, which engages with the upper stone, is the only piece employed to communicate motion thereto. * * * The wheel rotates upon a pivot within a socket formed in the centre of the transverse brace of the frame *O F*, which serves to regulate the distance between the two millstones by means of a screw. * * * The wheels which one sees manufactured in the style of this one, have their spoon-shaped arms assembled to the spindle, simply by a tenon and dowel pin; they are reinforced from beneath by means of brackets which maintain them all uniformly. * * *

"Others are constructed as shown in plan view *M* (*Fig. 22*) and its transverse section *N*, which a single inspection will render sufficiently comprehensible without further explanation."

Coming now to a type of wheel more nearly resembling modern constructions we quote further:

"It appears, in fact, that the remarkable disposition of the water wheels

* Fourneyron began his studies of the turbine in the year 1823, and erected his first wheel in France in 1827.

at Basacle (in the vicinity of Toulouse) is that which Borda had in view in the theory which he has given of a particular kind of horizontal wheel with curved pallets. (Ácademie des Sciences, 1767.) Referring to (*Fig.* 23) *M N* is the horizontal wheel in question, taking for instance a wheel furnished with curved blades such as *C D*, and that water directed by a tube *B C* is introduced between the pallets tangentially to their curvatures, and flows off at their lower extremity *D*, towards *E*.

"The theory very properly indicates the manner in which wheels of this style should be arranged, in showing that the only object in view is to regulate the movement in such wise that the water shall leave the wheel with no

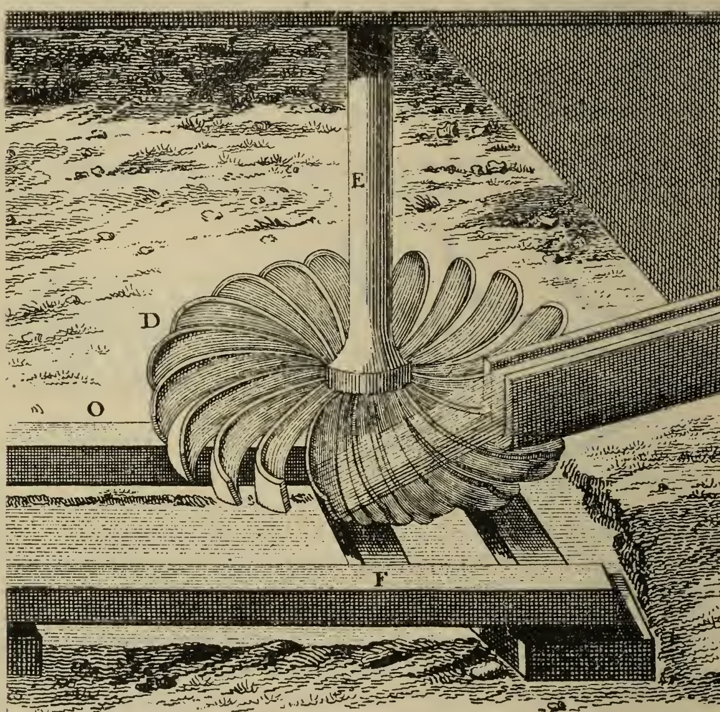


FIG. 21.

velocity, and therefore imparts to the wheel the entire momentum which it might have acquired in passing freely through the entire course of its fall.

"The theory also supposes essentially that the water, in entering the wheel at *C*, experiences no shock. This condition is filled by giving to the tangent of the curve of the bucket at *C*, the direction of the movement of the water at the instant when it commences to run along said bucket.

"In representing by *BC* the velocity $\sqrt{2gh}$ of the water when it arrives at *C*, and by *BF* the velocity, *V*, of the wheel, the line *FC* will represent, in length and in direction, the velocity with which water commences to pour into

the wheel, and, in consequence, the first element of the curve of the bucket at *C* must be in the direction of this line.

"The curvature of this bucket is indeed indifferent, provided it offers no angular bends, and that the direction of the tangent at the point *D* of exit of the water be as nearly horizontal as possible, without interfering with the discharge of the water.

"It will always be desirable to give to the vein of water and to the buckets only slight width in the direction of the radius of the wheel, because as the speed of rotation is not the same for the points at different distances from the axis of rotation, there is never but one point of the bucket which can have a speed capable of giving the maximum effect.

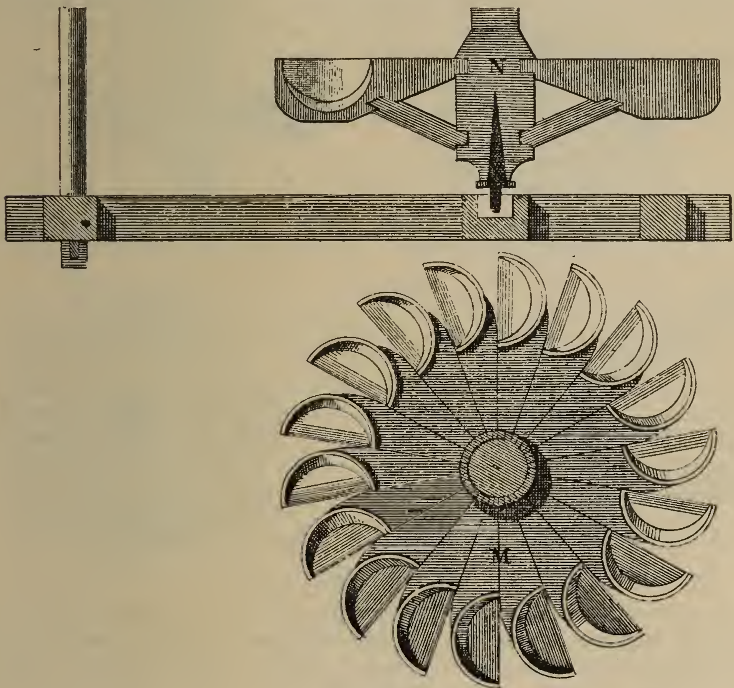


FIG. 22.

"If one had a large quantity of water, it could be caused to arrive by several tubes or inclined inlets distributed around the periphery of the wheel in vertical planes tangent to its circumference.

"One could, also, as Euler proposed in 1754, receive the water in a cylindrical vessel, having a diameter equal to that of the wheel, placed vertically above the same, and through which the shaft of this wheel would pass, and from which the water would escape by a number of inclined ajutages distributed at the circumference of the cylinder.

"Of all the water wheels which have been invented heretofore, I do not believe that there are any that show more ingenuity or more simplicity than

those which have been installed at Basacle, where there are twenty-five pairs of grindstones in line, each driven by a water-wheel, singly and similarly operated, and which maintain the flour supply of the city and suburbs."

These wheels are shown in plan and elevation in *Fig. 24*. They were surrounded by a cylindrical flume, to which the water was supplied tangentially, forming a whirlpool, and constraining the horizontal wheel which forms the bottom of the forebay to rotate with it. "The water which has entered into the forebay, after having previously effected several gyrations, and struck the buckets of the wheel, passes through the openings which exist between the said buckets, and escapes on the discharge side or tail-race, which is downwardly inclined. The wheel is mounted upon a square shaft rotating in a step bearing, levered upon a beam to which an adjusting screw is attached, which regulates the fineness of the grinding, the running stone being carried on the top end of the wheel shaft."

"This wheel, which is only 3 feet in diameter, is made in a single piece, from the section of the trunk of a large tree; the buckets are cut out at an

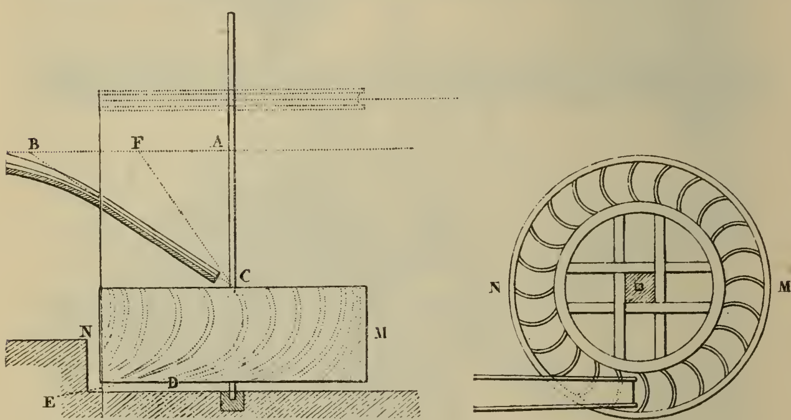


FIG. 23.

angle to the horizon, being slightly curved, as shown. In order to give to this wheel all the perfection of which it appears to be susceptible, there is room for several curious researches, into which, however, I shall not enter. I shall only say that the water which operates it causes it to act with a force composed of the action of its weight, and of the circular direction imparted to it by the cylindrical forebay, and that the curvature of the buckets should follow that of the development of a circle."

In the American edition of "Ferguson's Lectures," 1806, a description and cut are given of an undershot wheel having buckets inclined to the radius: "It is driven partly by the impulse, but chiefly by the weight, of the water; the 'mill course' descends to and directs the water into the wheel nearly in line with the buckets, which insures the impulsive action of the water." (See also *Dict. des. Sci.*, Paris, 1767, pl. vii, an undershot wheel with inclined buckets.) M. Lambert, of the Academy of Sciences, at Berlin, 1775, indicates the angle at which the floatboards should be placed. These

references show the tendencies of construction at that time toward favoring the impulsive action of the water as it enters the wheel.

Navier's notes on "Belidor's Hydraulic Architecture," published, 1819, p. 461, § 4, confirms the above in the following quotation: "The necessity of disposing machines in such wise that there should be no shock, although established long ago, both by theory and practice, is not so generally recognized as could be desired. * * * Mr. Brewster also announces that he has frequently had the idea that a hydraulic machine of great efficiency

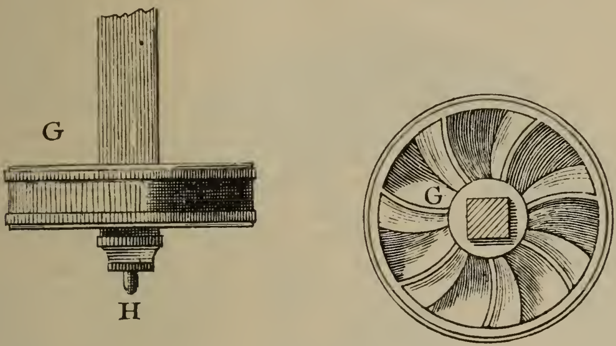


FIG. 24.

could be constructed by combining the impulsion with the reaction of water."

Zuppinger's so-called tangent wheel was one of the first types of radial outward- as well as inward-flow impulse turbines, intended to be used for high falls, for which the dimensions of reaction turbines, obliged to work full of water, would become impracticably small, "* * * such that the quantity of water used is only sufficient to act upon a few vanes at a time." (See "Bodmer's Hydraulic Motors," p. 39.)

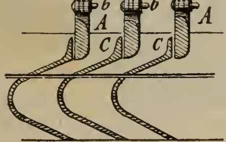


FIG. 25.

The curve of the buckets and the lines of water admission are fairly shown by Chenevals' turbine, in *Fig. 25*, copied from Dingler's *Polytech. Jour.* for 1857. (This figure may also represent the buckets of the Poncelet Turbine, for which see *Fig. 283*, Johnson's "Weisbach," 1849, p. 296.)

Vertical tangential wheels with outward flow were first constructed by Schwamkrug prior to 1850. (For this see Du Bois' "Weisbach," *Fig. 468*, p. 367, in which the buckets and guides are also well shown by *Fig. 25*.) The curved bucket for the initial tangential action of the water is very apparent in all these cases.

From Rees' Cyclopedia, American edition, 1810–24: "The Chevalier de Borda observes that in theory a double effect is produced when the float-boards are concave, but that the effect is diminished in practice, from the difficulty of making the fluid enter and leave the curve in a proper direction. Notwithstanding this difficulty, however, and other defects which might be pointed out, horizontal wheels with concave float-boards are always superior to those in which the float-boards have plain surfaces."

At the meeting of the Institution of Civil Engineers, London, for March 22, 1842, Prof. Gordon said:

"Poncelet was led, in 1824–25, to the invention of the 'undershot wheel with curved floats,' the efficiency of which has been found equal to from sixty-five to seventy-five per cent. The velocity of this may be fifty-five to sixty per cent. of that of the effluent water—a velocity equal to that due to nearly the whole height of fall; hence the efficiency becomes 'about double that of the ordinary undershot wheel.'

"The construction of the Fourneyron turbine may be compared to one of Poncelet's wheels with curved buckets laid on its side, the water being made to enter from the interior of the wheel, flowing along the buckets, and escaping at the outer circumference; centrifugal force here becomes a substitute for the force of gravity. The water, when admitted to the reservoir, rises to a certain level, exercising a hydrostatic pressure proportional to the height of the column, and on the sluice being raised it escapes with a corresponding velocity in the direction of the tangent to the last element of the guide curves, which is tangent to the first element of the curved buckets. The water pressing without shock upon the buckets at every point of the inner periphery, causes the wheel to revolve, then passes along the buckets, and escapes at every point of the outer periphery.

"M. Poncelet, in his lectures at Metz, had given, in 1826, a description and theory of a wheel with curved buckets and a vertical axis, analagous to his wheel of the same species of which the axis is horizontal, and which received the water without shock through many points of its exterior circumference, and allowed it to escape without velocity through the interior."

From DuBois' "Weisbach," Vol. II, p. 316, we quote: "When the floats of undershot wheels are curved in such a manner that the entering jet of water is allowed to flow along their concave sides and press against them without causing any shock, a greater effect is obtained than when the water strikes more or less perpendicularly against plain floats. Such wheels with curved floats are called after their inventor, Poncelet's wheels. * * * (*Fig. 26.*) To obtain as great an effect as possible with one of Poncelet's wheels, it is necessary that the water should enter the wheel without any shock. * * * "The water ascends the float like a solid body, with decreasing velocity, while at the same time it has the velocity of revolution of the float. Having attained a certain height, it has lost all its relative velocity, and now falls down along the float with accelerated motion, so that at last it arrives again at the outer end of the float, with the same velocity with which it began to ascend.

"Poncelet himself experimented upon the performances of these wheels, the records of which were made in a special work published in Metz in 1827.

"'The Poncelet wheel (says 'Bjorling,' p. 24) is classed by some authorities under the head of turbines, because they are actuated by the force due to the

rapidity of the current of water and the impulse due to the head and fall combined. The water is admitted down an incline of one in ten, on a curved race, so as to enter the wheel without any shock.' The first idea of an inward-flow tangential wheel is due to Poncelet.

"The object of the curved approach-way for the water, in the Poncelet wheel, is to lay the whole of it onto the wheel without impact, and not the top and bottom strata only; since in these wheels, in order 'to obtain the maximum efficiency, the water must go onto the buckets without impact,' thus providing for the water a higher order of contact."

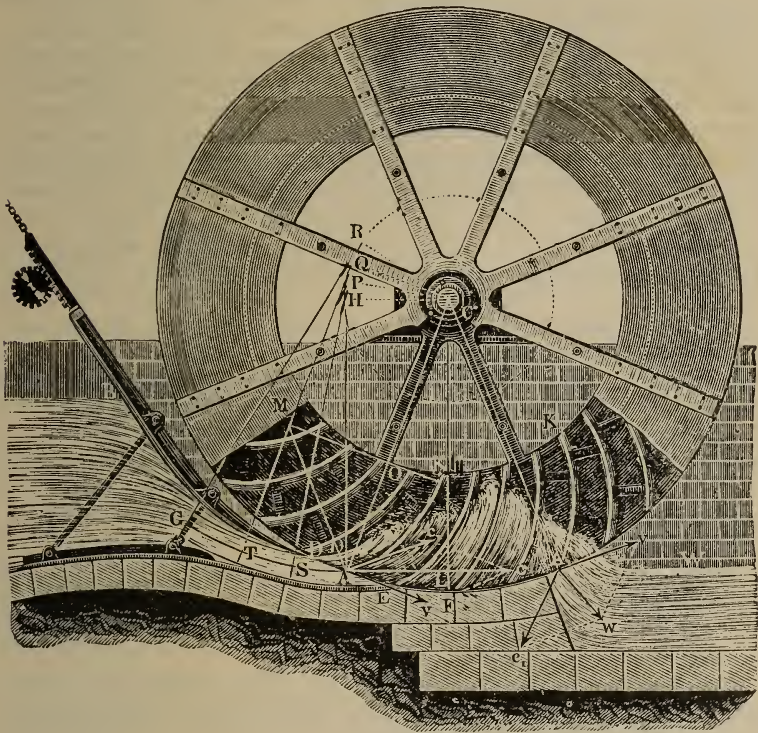


FIG. 26.

In the French patent of M. Callon, October 19, 1840, No. 7,878, the following statements are made:

"These general equations (algebraic) apply, without exception, to all wheels with vertical axes in which the water arrives with a certain velocity and in any direction, and acts by moving itself upon the floats, or in the canals fixed to this wheel. They express that the water enters without shock into the wheel and goes out without velocity. Simplifying these equations they become identical with those given by Navier, and which relate principally to wheels, whether they receive the water upon only one point of their circumference, or receive it at the same time upon the whole circumference, a dispo-

sition which was proposed for the first time by Euler in the year 1754, and which, consequently, is in the public domain. * * * In order that the conditions of the movement of a turbine be as advantageous, and, at the same time, as simple as possible, there must be no shock, and, consequently, no disturbance in the movement of the water.

"It is well understood that the inclination of the guides, or, more broadly, the inclination of the canal which brings the water, relatively, to the axis of the wheel, and the inclination of the first element of the buckets or blades, shall be so combined as to avoid all shock at the entrance." * * * "It is not necessary to go further to see that the theory of the turbine, with horizontal axle, is exactly the same as that of the turbine with vertical axle."

In Dingler's *Polytechnisches Journal*, vol. cxxv, of the year 1842, and in French patent, No. 2,909, 1847, is pictured and described de Canson's tangential wheel. It is somewhat like Fourneyron's, except that the water is directed upon the inner ends of the buckets in the form of a jet, and escapes from the wheel at its outer circumference tangentially thereto. Mr. de Canson had been engaged making these wheels for a long time prior to this publication.

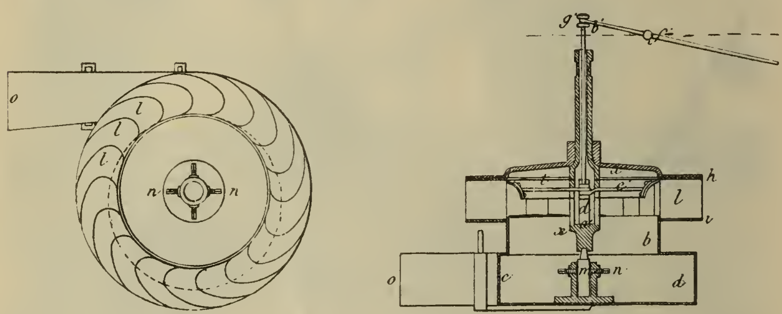


FIG. 27.

tion. He called them *rural turbines*, on account of their great simplicity. They were made to suit any fall of water, from $\frac{8}{10}$ of a meter to 6 meters and over, and gave, under proper working conditions, an efficiency of sixty-seven per cent.

The patent of the wheel of Madame de Girard, at Paris, bearing date March 8, 1843, and number 7,798, is for a turbine without guiding buckets. "This system of wheels with curved pallets is distinguished from all those already known, in that the water, acting from the inside to the outside, arrives between the blades in a direction tangent to the interior of the wheel, without having recourse to the guiding buckets by means of which in the Fourneyron turbines the fluid is given a direction more or less approaching to the tangent.

"We attain this result more exactly still by giving to the passages between the buckets, *l*, *l*, *l*, in the crown, or running wheel, a double curve, in such wise that the water, entering without shock in the direction tangential to the helix, which it follows necessarily, in leaving the cylinder, shall be brought back by a continuous curve in a horizontal direction. (See *Fig. 27.*)

"In order to regulate the ascent of the gyrating water we give to the

bottom of the cylinder a helicoidal form, such that the height of the first turn of this helix shall be equal to the height of the interior opening of the inlet, as indicated by the dotted line" in plan of *Fig. 27*.

Regarding this invenion, it is safe to say that, the principle involved in the semicircular form of buckets permitting the tangential entrance of the water in one direction and its discharge tangentially in the reverse direction, was so well known and understood in the art at the time, that no claim is based thereon, and no mention is made in the patent beyond the facts quoted.

From *Dingler's Polytech. Jour.*, for 1843, vol. xcv, we quote: "Nagel's turbine is a wheel of the Fourneyron type, but differs from this justly celebrated motor in that the water approaches the wheel from below. This, however, is not new, as Mr. Wedding, of Berlin, made turbines many years ago, into which the water was directed upwards to the wheel."

The most important feature to which we desire to call attention, is the double curvature of the buckets in the wheel, which are parallel to the wheel's axis, and are so formed that the guides join with them in easy curves, such that the water is laid upon all the buckets at once without impact, and reverses the direction of its motion within the wheel, leaving the wheel tangentially to its course. The shape of the buckets is identical with those of Madame de Girard's patent.

Bodmer, in his *Hydraulic Motors*, 1889, p. 41, informs us that: "The French engineers, Callon and Girard, commenced in 1856 to design impulse turbines for all possible conditions, high and low falls, large and small quantities of water. These turbines were made both axial and radial, with horizontal, vertical and inclined axes. The impulse turbine has, in consequence, become associated with the name of Girard, and every variety of impulse turbine now goes by the name of a 'Girard' turbine."

Mr. Atkins' first application for United States patent was in 1853, which places him in this line of invention ahead of M. Girard. What happened in these particulars during the century preceding Atkins' invention, this appendix fully sets forth. But inasmuch as every point in the Atkins patent, with which the Pelton invention might be construed to conflict, was known and used before Atkins' time, we have no need of instituting comparisons in this inquiry. Furthermore, in the allowed patent of Atkins, dated August 10, 1875, there is not a word said about the impulsive action of the water upon the wheel, or of the necessity of employing such action in order to obtain better results.

The only claim in this patent which, by construction, as shown on the drawings, would secure the impulsive action of the water, is restricted to a combination of the chutes, which direct the water on to the wheel, with the buckets of the wheel having circular passages of uniform width and an area of water-way double that of the chutes.

Referring to impulse turbines of the Girard and like types of wheels, Bodmer cautions against the liability of choking in the buckets, especially towards their outlets, where there is the greatest risk of this occurring. He also refers to the loss of energy during partial admission of the water, "owing to the fact that a portion of the stream on entering a bucket does not come into contact with the upper end of the same, but impinges on the latter much

lower down, the result being a sudden instead of a gradual change of direction and consequent shock."

These effects cannot happen in the Pelton wheel, because, by construction, the jet is always directed towards the edge of the wedge, forming the initial surfaces of the bucket's curvature, and cannot *begin* to act at any other place. The other defect referred to, to which impulse turbines are liable, except with finer bucket pitches, is impossible of occurrence in the Pelton wheel, because the discharging edges of the buckets, far from being confined in area by adjacent buckets, always give an unobstructed discharge.

In Armengaud's *Pub. Industrielle* for the years 1874–'78–'79–'82–'85 and '86, will be found figured and described a variety of wheels, in which the water is laid on to and received by their buckets in a direction tangential to the motion of the wheels. The water inlets are single and multiple, with means of area regulation; some have straight and some curved guide waterways; all of them have curved wheel buckets, which more or less approach a semicircle in form. *Figs. 20* and *25* may be referred to as giving in general the form and disposition of their waterways.

"Schiele's turbine is a double one, with curved buckets starting from a central midrib. The water is conducted to the wheel in a spiral chamber surrounding it, from which it is guided through narrow ports onto the middle of the wheel's circumference, in such direction as to enter equally the upper and lower buckets of the wheel without shock or turbulence, giving its power to the wheel by a steady pressure while passing along the curved buckets, and issuing from both sides of the wheel to the tail-race, quietly and silently—a clear proof that the whole of the power has been absorbed.

"In thus acting toward *both* sides of the wheel when the same is horizontal, the water exerts no pressure whatever on the foot-step. The wheel is so proportioned that more water is directed to the upper half, and thus balances the weight of the wheel and its attached parts." (See *Prac. Mech. Jour.*, vol. vi, 1861.)

This turbine is noted, because it is the only one found possessing any resemblance to a Pelton water wheel, but since it is surrounded by a water-trunk applying the water to all the buckets at once, and is not adapted to receiving it from a single jet, we do not deem it an anticipatory reference.

To find all the data relating to any particular detail of a water wheel is not an easy task. The following will explain. Mr. James B. Francis, in the year 1855, in his "Hydraulic Experiments" says: "* * * it was said several years previously that not less than 300 United States patents have been granted for reaction wheels and improvements upon them; they continue to be the subject of almost innumerable modifications. Within a few years there has been a manifest improvement in them, giving a useful effect approaching sixty per cent. of the power expended."

The main difficulties with turbines lie in their construction, and these, it is said, M. Fourneyron overcame by long experience, the secrets of which he kept to himself during many years. If we add to these statements another fact—"the records of the earlier turbines are locked up from many readers in a foreign language"—the obstacles which lie in the way of a thorough inquiry into even the leading elements of the theory and practice of hydraulic motors will be found to be well-nigh insurmountable.

The preponderance of testimony here given favors the increased efficiency of wheels with buckets having double curvature. We may therefore, offer the converse and equivalent of this as expressed in Mr. Ellwood Morris' conclusion, in *Jour. Frank. Inst.* for 1843: "To satisfy the condition of maximum effect in hydraulic motors, the water should enter and act upon the wheel without shock and escape from the wheel without velocity."

In order, therefore, to get the advantage here declared, a wheel must have buckets approximating the half-circle form, a construction long in the public domain, and which could not, therefore, properly be claimed as new in the latter half of this century.

The devices for securing high efficiencies are multitudinous along the path of turbine achievement, and on "the principle that their commonness shows their usefulness," as was said, by Desaguliers, in 1744, it seems amazing as we come to know, in retrospect, the inventions of the past, that perfection was not reached long ago.

To have brought a jet wheel to a working efficiency of eighty-six per cent. and over—making it rank with the best and most elaborately designed and constructed turbines—is certainly, therefore a remarkable feat accomplished in hydraulic engineering.

The impulse of water as a method of transferring the living force of a moving liquid to a wheel is an important inquiry in this connection, and we have shown it to be an ancient invention, as compared with a live patent; but our business is not so much to demonstrate the principle of impulsive action, as to exhibit the devices for securing effects; to show plainly the means that have been employed to get the most work out of a given head and quantity of water; that is, the wheel itself. It is the invention of Pelton, not a claim for the principle of impulsion, upon which we are to report.

In conclusion the following efficiency tests are added:

Mr. Ross E. Browne says: "In experimenting with the 'curved buckets,' the efficiency might possibly have been raised two or three per cent. by attending more carefully to the curve and to the size nozzle used. Still there was probably a gain of more than twelve per cent. due to the introduction of the wedge in the Pelton bucket.

* * * "In the year 1884, the proprietors of the Idaho mine, near Grass Valley, Cal., having determined to introduce water-power in the place of steam, invited all the water-wheel dealers and manufacturers on the Pacific Coast to make a public test with reference to determining the efficiency and adaptation of the various wheels to their service. This invitation was responded to by some four or five representatives of the most prominent wheels. The tests showed the Pelton wheel to be 'nineteen per cent. in excess of the best showing made by any of the others. The test of the Pelton wheel there made proved the useful effect to be 87·3 per cent."

Prof. Irving P. Church (*Mechanics of Fluids*. New York: Wiley. 1889), in his discussion of the Pelton water wheel, gives the Pelton motor "a theoretical efficiency of unity, the water leaving the buckets without velocity. The wheel in practice utilises eighty to eighty-five per cent. of the issuing water."

Professor Dwight Porter, associate professor in the Department of Hy-

draulic Engineering of the Massachusetts Institute of Technology, communicates the following:

"The four-foot Pelton water wheel in our hydraulic laboratory has been used in regular class tests for one season only, with the following results: In twenty-two tests with a one and three-eighth inch nozzle tip in use, under heads ranging from fifty-four feet to 171 feet, the velocity of rotation in no case varying more than eight per cent. from the theoretical best velocity, the efficiency has ranged between 71·2 per cent. and 81·4 per cent. for the entire series."

[Extract from a paper entitled "Water Motors as Marine Dynamo Drivers," by Lieut. F. J. Haeseler, U. S. N., published in the U. S. Naval Institute. U. S. Naval Academy, May 11, 1895.]

THE WATER MOTOR.

"The water motor used in the above-described comparison is manufactured by the Pelton Water Wheel Company, of San Francisco and New York. I have tested other makes of water motors and read of still other tests, and it has been my experience, as well as that of others making comparative tests with these motors, that they are at least fifteen per cent. and in some cases thirty-five per cent. more efficient. The firm claims an efficiency of eighty-five per cent. when the wheels are set in accordance with their instructions, and I have found their claims not only true, but below what is really obtainable. During the past two months Ensign W. H. G. Bullard, U. S. N., and the writer tested one of the Pelton wheels bought out of stock two years ago and without any expectation at that time of its being tested for efficiency.

"Tabulated below are the results of our tests, showing an efficiency at the higher pressures in excess of that claimed by the firm.

"Tests Nos. 1, 2, 3, 10 and 11 were made with the motor running at incorrect number of revolutions in order to determine the efficiencies when governing, in case the pressure on the whole jet was reduced and the revolutions kept up. Test No. 13 was the last one made, and it was noticed that the brake was binding closely on one side, which may have occasioned the lower efficiency.

TESTS OF PELTON WATER MOTOR No. 4.

MADE BY LIEUT. F. J. HAESELER, U. S. N., AND ENSIGN W. H. G. BULLARD, U. S. N., AT THE UNITED STATES NAVAL ACADEMY, MARCH, 1895.

No. Test.	*Size Jet. Inch.*	*Running Pressure.*	*Revolutions.*	*Actual Water Used.*	*Actual H. P. Developed.*	*Theoretical H. P. Possible.*	*Per Cent. Efficiency.*
1 . .	⅝	90	775	14·05	4·101	5·496	74·6*
2 . .	⅝	105	910	15·14	5·025	6·910	72·7*
3 . .	⅝	100	850	14·78	4·694	6·422	73·1*
4 . .	⅝	100	775	14·78	5·349	6·422	83·3
5 . .	⅝	103	780	15·00	5·563	6·715	82·9
6 . .	⅝	125	880	23·05	10·73	12·52	85·69
7 . .	¾	102	775	20·82	7·845	9·226	85·02
8 . .	¾	100	775	20·61	7·756	8·957	86·59
9 . .	¾	125	900	23·05	10·67	12·52	85·16
10 . .	¾	73	775	17·61	4·457	5·587	79·79*
11 . .	¾	86	880	19·11	5·365	7·143	75·12*
12 . .	¾	100	780	20·61	7·717	8·957	86·15
13 . .	¾	142	900	24·56	12·84	15·16	84·70

* Tests marked thus (*) were made to find the efficiency of the governor. The motor was running at incorrect number of revolutions at the time for the pressure at the jet. The water used is in cubic feet.

"A Prony brake was used, with a stream of cold water running over it all the time, and two pieces of soap bearing against the pulley, like the brushes of a dynamo, kept the brake equally lubricated, and the pull on the scale was very steady. The pull was measured by a spring balance, the brake arm being kept horizontal all the time, and the balance was compared with the standard after each test, and in several cases the standard itself was used. The standard balance was verified before and after the series of tests, and was found to be accurate. The amount of water used was *absolutely measured* by running it into the pool of the natatorium of the Naval Academy, where the level of its surface could be measured by means of a float and rod, that could be read with exactness to the one-sixty-fourth of an inch, which corresponded to just one cubic foot. In this manner, a number of tests were made, and the coefficient of ajutage found to be ninety-five per cent. with the five-eighth inch jet, and ninety-two per cent. with the three-quarter inch jet, which agrees very closely with what they should be when worked out theoretically. After the coefficients were determined and found to be practically constant, the five-eighth inch jet not varying one per cent. in a range of pressures from 20 to 100 pounds, and the three-quarter inch jet not varying at all in from fifteen to fifty pounds, the water motor was moved to the power-house close to the pump, so as to get rid of pipe friction, and to have the pressures more under control. The amount of water then used was determined by using the coefficients of ajutage found as already described. The efficiencies thus determined can, therefore, be taken, as being reliable, and agree with those in testimonials published by the Pelton firm."

The case is clear, in the light of all our searches, that the bucket of Pelton is absolutely new, correct in principle and commercially important.

No. 4724 Springfield Avenue, Philadelphia, June, 1895.

ASPHALTS AND BITUMENS.

By Samuel P. Sadtler, Ph.D.,
Professor of Chemistry in the Institute.*

In taking this subject for a short review, let us inquire as to the meaning of these words and the use that has been made of them. Here at the outset we are met with a considerable divergence of view and latitude, not to say looseness, of application.

In "Mineral Resources of the United States for 1893," published by the United States Geological Survey at Washington, we find, on page 627, under the heading "Asphaltum," the following statement: "Under this generic name one finds included bituminous rock, sandstones and limestones impregnated with bitumen or asphaltum, free bitumens, either liquid, viscous or solid, containing little or no mineral matter, and, finally, mixtures in various proportions, more or less intimate, of bitumens with inorganic matter, or with both inorganic and organic matter." This certainly is a wide range of application for the term asphaltum. On the other hand, Léon Malo and other French writers have sought to narrow its application to one class of natural product, as will be seen from the following quotation:

"Asphalt is a natural product, a bituminous limestone in which carbonate of lime and pure mineral bitumen are most intimately combined by natural agency, the proportions varying from seven per cent. bitumen and ninety per cent. carbonate of lime to two per cent. bitumen and eighty per cent. carbonate of lime."†

Similarly, Capt. F. V. Greene, in a paper read before the American Institute of Mining Engineers, October, 1888,

* A lecture delivered before the Mineralogical Section of the Brooklyn Institute, December 18, 1894, and repeated at the Franklin Institute by request.

† "Twenty Years Practical Experience of Natural Asphalt." W. H. Delano. E. and F. Spon. 1893.

after taking exception to Léon Malo's restricted use of the word, gives a table of the various forms of bitumen in which he limits the application of the word asphalt to "bitumen mixed with earthy matter," excluding, however, bituminous sandstones and bituminous limestones.

To clear up this matter and define in sufficiently broad, but exact terms, the proper use of the word asphalt, we must first refer to the meaning of the other term which I have used in choosing a subject for this lecture, viz.: *bitumen.* The word bitumen in mineralogy is applied to hydrocarbon mixtures of mineral occurrence, whether solid, liquid or gaseous. With this understanding of the nature of bitumen, we can adopt the very concise classification of Prof. S. F. Peckham, who published, in 1885, the "Special Report on Petroleum" for the tenth census. It divides bitumens into:

Solid: Asphaltum (German, *Asphalt* or *Erdpech;* French, *Asphalte*). *Semi-fluid: Maltha* (French, *Gondron minéral;* Spanish, *Brea*). *Fluid:* Petroleum. *Volatile:* Naphtha (German, *Naphta*). *Gaseous:* Natural Gas—of burning springs.

According to this classification asphaltum is simply a solid bitumen. It may be almost pure, as the so-called "Glance-pitch," Gilsonite, or Grahamite, and find its chief application in asphalt varnish making; or, it may contain earthy matter, varying in amount from two or three per cent. to the ninety per cent. of the so-called asphalt rocks.

The same classification has been adopted by Major J. W. Howard, in his pamphlet, "Natural Asphaltum and its Compounds," and by his courtesy I am enabled to show you his "Table of the Occurrence of Important Natural Bitumens," the most complete enumeration that, so far as I know, has been made:

Important Natural Bitumens.	Natural gas			Ohio, Pennsylvania, California, etc., in the United States, Russia, France, etc.
	Natural naphtha			Found in petroleum districts (of little value, superseded by artificial naphtha from crude petroleum).
	Petroleum			Pennsylvania, Ohio, Wyoming, California, etc., in United States, Russia, etc. (Consult books on petroleum.)
	Maltha			California, Wyoming, Alabama, Utah, Colorado, Kentucky, New Mexico, Ohio, Texas, Indian Territory, etc., Russia, France, Germany, etc.
	Asphaltum	Asphaltum Almost Pure.	North America	Utah, California, Texas, etc.
			Central America	Cuba, Mexico, etc.
			South America	Trinidad, Venezuela, Peru, Colombia, etc.
			Europe	Caucasia, Syran on-the Volga, Germany, France, Italy, Austria, etc.
			Asia	Hit on the Euphrates, Asia Minor, Palestine, etc.
			Africa	Oran in Egypt, probably other places.
		Asphaltic Compounds.	North America	West Virginia, Kentucky, Texas, Wyoming, Utah, Colorado, California, Indian Territory, Montana, New Mexico.
			Central America	Mexico, Cuba, etc.
			South America	Trinidad (largest supply, most used), Venezuela, Peru, Colombia, etc.
			Europe	Germany, Switzerland, France, Italy, Sicily, Russia, Austria, Spain, etc.
			Asia	Asia Minor, Palestine, Bagdad, and probably in China.
			Africa	Egypt and probably elsewhere in Africa.

We may now take up for special description the two classes of bitumens: the Malthas (or semi-liquid bitumens) and the Asphalts (or solid bitumens).

One of the earliest known and most famous occurrences of maltha or mineral tar was that of Bechelbronn in Alsace, which was described and studied by Boussingault. It is described as a viscid, tarry liquid, of bituminous odor, and a specific gravity 0·966. It was from this maltha that Boussingault obtained the products to which he gave the

names "petrolene" and "asphaltene," and which have played such an important part in asphalt literature. Kayser, who re-investigated the Bechelbronn maltha in 1879, considers that it is a solution of a sulphated hydrocarbon (asphaltene) in a liquid sulphur-free hydrocarbon (petrolene), and that the latter is present in much the larger amount. In his ultimate analysis of the maltha, Kayser notes, however, over 0·3 per cent. of nitrogen as also present.* This deposit has long since been worked out.

In this country mineral tar or maltha is found in a large number of States, especially in the West. The most important occurrences are those of southern California, in the counties of Kern, Ventura and Santa Barbara. Crude maltha or mineral tar, as found in California, is often mistaken for a heavy petroleum, or rather a petroleum residuum, as its gravity, 12° to 17° Baumé, corresponds with that obtained in such residuums; but, as pointed out by Professor Peckham, it differs in important particulars. The maltha in its crude state contains from twelve to fifteen per cent. of water, which will not settle out, but must be removed by heating to from 212° to 300° F. The amount of water retained by crude petroleums, incapable of settling out, on the other hand, is slight, not over one to two per cent. The crude maltha usually contains air, carbon dioxide, or hydrogen sulphide, in varying proportions, mechanically mixed with the viscous mass, so that when the maltha is heated to not more than 100° F., it begins to froth rapidly, and will usually fill both still, condenser and receiver with an overflow of foam before any of the water has been removed.

These malthas, likewise, contain, in the natural state, volatile oils and basic hydrocarbons, both of which have to be removed in the refining process.

Similar to this occurrence of natural malthas, although distinct from them, in respect of the conditions required for its extraction and possibly also in chemical characters, is the so-called "liquid asphalt" obtained at Las Conchas mine, some thirteen miles east of the city of Santa Barbara, in Santa

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* *Untersuchungen über Natürliche Asphalte*, p. 20.

Barbara County, Cal. Here is found a bed of clean sea-sand, holding, like a sponge, the thick maltha, which oozes up from underlying beds of shale.

It is stated that a well sunk 400 feet in this lower stratum continues to ooze maltha at all points. The mine is right on the edge of the ocean, and the sands extend some miles back from the beach. Covering the sand deposit is a surface deposit of light earth and soil, upon which is ordinary vegetation. This soil is "hydraulicked" off by a twelve-inch stream of clear salt water, and the maltha-containing sand uncovered. The separation of the maltha from the sand is accomplished not by distillation, but by mechanical means, and with the aid of specially designed machinery, by the California Petroleum and Asphalt Company, which sells it under the name of "Alcatraz liquid asphalt."

Crude maltha, under the several names of "liquid asphalt" and "mineral tar," is found also in Utah, Kentucky, Tennessee and Texas, although in most cases no attempt has been made to utilize these products commercially.

Let us pass now to solid bitumens or asphalts in the proper sense of the word. The purest of the solid bitumens are known sometimes as "glance-pitch" or "gum asphaltum." Prominent among them is the gilsonite of Utah. This is found in the Uintah Indian reservation in Wasatch and Uintah Counties. The purity of the gilsonite (some ninety to ninety-eight per cent. soluble in carbon disulphide), is such that it finds large application in the manufacture of varnishes and insulating compounds. The present production is some 2,000 tons annually. Glance-pitch also occurs in Texas, in Cuba and Mexico.

We come then to the asphalts which contain inorganic matter in varying amount as a uniform constituent of the mineral as it occurs in nature.

The two most important occurrences of these asphalts are those of the island of Trinidad, known as the Trinidad Lake asphalt, and of the province of Bermudez, in Venezuela, on the mainland, nearly opposite the island of Trinidad, and known as the Bermudez Lake asphalt.

The so-called "Pitch Lake" of Trinidad occurs on the west coast of the island. It is situated about a mile and a half from the sea coast, at a height of 138 feet above sea level, and occupies the crater of an old mud volcano. It forms, therefore, a circular mass of asphalt of an area of a little more than 114 acres, and of uncertain depth. Rude borings have been made which indicate a depth of seventy-eight feet in the center and about eighteen feet at the sides. If these figures are correct, the lake should contain about 6,000,000 tons of asphalt. Too much confidence, however, cannot be placed upon these borings, as the asphalt near the center seems to be softer than that around the edges and seems to rise readily to replace the portions removed. Whether the lake or deposit of asphalt is still fed from underground sources, as has been suggested by some authors, is not definitely known. While the term lake is used, it must not be supposed that the surface resembles that of a liquid, even a viscid liquid. On the contrary, the surface shows a brownish, earthy material, with cracks or fissures here and there of a width and depth of several feet, some filled with rain-water, and some with earth, supporting a scrubby vegetation. Carts and mules, it is stated, can be driven everywhere on the surface. The material is dug with a pick and shovel, loaded into carts, and hauled to the beach to be loaded on lighters which carry it to the vessels. During the voyage to this country, the material unites into a solid mass, and must be removed from the hold by the use of the pick and shovel.

The crude Trinidad Lake asphalt has the following composition:

	Per Cent.
Bitumen	39·83
Earthy matter	33·99
Vegetable matter	9·31
Water	16·87
	100·00

After a refining process, in which it is heated in large tanks to a temperature of not much over 300° F., in order to drive off the water and allow portions of the earthy

matter to settle and of the vegetable matter to be skimmed off, it has the following composition:

	Per Cent.
Bitumen (by CS_2)	59·86
Earthy matter	35·82
Vegetable matter	4·32
	100·00

Besides this lake asphalt, the island of Trinidad also yields a "land asphalt," from the neighborhood of the lake.

This asphalt may have come from overflows of the main deposit in past ages, or it may have an independent, although analogous, origin. It seems harder and more earthy than the lake deposit, and its bitumen shows differences in solubility and other physical properties.

The exportations of the Trinidad Lake asphalt have increased rapidly in recent years, and amounted in 1892 to 96,319 tons, and in 1893 to 88,881 tons.

The Bermudez asphalt also comes from a so-called "pitch lake," situated in the State of Bermudez, in the republic of Venezuela. The deposit is some eighteen miles from the mouth of the San Juan River, which empties into the Gulf of Paria, opposite to, and about one hundred miles distant from, the island of Trinidad. A narrow-gauge railroad runs from the shipping point, Guanoco, on the San Juan River, to the lake, a distance of six miles. The deposit, or lake, covers an area of over 1,000 acres, and is of unknown depth. While vegetation is found growing in irregular patches over the surface, it is only superficial, and a uniform deposit of asphalt is found underneath.

The Bermudez asphalt, as dug from the lake, is a solid bitumen of great purity, containing, according to an analysis recently made, but 2·63 per cent. of mineral matter and about 1·3 per cent. of organic non-bitumen, with several per cent. of water, leaving over 90 per cent. of bitumen soluble in carbon disulphide.

The refined asphalt, obtained by a process similar to that spoken of under Trinidad asphalt, is slightly purer, being:

	Per Cent.
Bitumen (by CS_2)	97·22
Mineral matter	1·50
Organic non-bitumen	1·28
	100·00

This asphalt is, of course, notably softer and more plastic than the Trinidad Lake asphalt, which in its refined state carries some 35 per cent. of mineral matter (chiefly clay and oxide of iron) as compared with 1·50 per cent. of the Bermudez.

The natural asphalts (or solid bitumens) of California are also very important and of a high degree of purity. Thus, the La Patera mine, situated twelve miles west of Santa Barbara, and at a depth of 125 feet, yields a compact solid rock of the composition:

	Per Cent.
Bitumen soluble in CS_2	59·15
Mineral matter	39·75
Organic non-bitumen	1·10
	100 00

The deposit covers several hundred acres, and is mined much in the same manner as coal. It is not soft, but is friable, and breaks readily under the pick or wedge. The mineral residue is fine silica, free from clay and organic matter.

Similarly in Kern County, California, are extensive deposits of a solid asphaltum worked by the Standard Asphalt Company. This material in its crude state shows the following composition:

	Per Cent.
Bitumen soluble in CS_2	84·79
Mineral matter	8·70
Organic non-bitumen	traces
Moisture	6·51
	100·00

An interesting feature in connection with this asphalt is that the mineral matter consists almost entirely of infusorial earth, or silica of organic origin, possessing a peculiar absorbent character.

Other asphalts of this class, that is, solid mixtures of bitumen and earthy material, are those of Cuba containing some seventy per cent. of bitumen, and of Syria containing from seventy-five to ninety per cent. of bitumen.

We have now to consider the case of bituminous or bitumen-saturated rocks. These are included in two classes: Bituminous limestones and bituminous sandstones. The former class includes the best known and most generally used asphalts of Europe. We have among these the mines at Seyssel-Pyrimont in the Department of Ain, France; those of Val de Travers in the Canton of Neufchatel, Switzerland; those of Ragusa in the island of Sicily; of Limmer, near Hanover, Germany; and of Vorwohle, in Germany. These asphalts are in general composed of a fine amorphous limestone, saturated with from five to fourteen per cent. of bitumen. The subjoined analyses, taken in part from Howard's pamphlet and in part from the "Mineral Resources of the United States for 1893," will show the composition of these asphalts:

	Seyssel, France.	Val de Travers, Switzerland.	Ragusa, Sicily.	Limmer, Germany.	Vorwohle, Germany.
Bitumen	8·15	10·15	8·92	14·30	5·37
Calcium carbonate	91·30	88·40	88·21	67·00	90·80
Magnesium carbonate	·10	·30	·96	—	—
Clay and oxide of iron	·15	·25	·91	17·52	·59
Sand	—	—	·60	—	2·55
Insoluble	·10	·45	—	—	—
Loss	·20	·45	·40	1·18	·34
	100·00	100·00	100·00	100·00	100·00

One very characteristic occurrence of bituminous limestone is found in the United States, viz.: the so-called litho-carbon in Uvalde County, Texas. The mineral here found, according to "Mineral Resources of the United States for 1893," is a bituminous limestone, the limestone being a shell deposit, in which the original forms are still maintained. The rock contains from fifteen to thirty-three per cent. of bitumen, the average being about twenty per cent. The refined product is said to possess peculiar

properties, being especially noted for its elasticity, making it, in this respect, somewhat similar in character to elaterite.

In this country the bituminous sandstones occur chiefly in California, Utah and Kentucky. In the State first named these sandstones are found at various points between San Francisco and Los Angeles, in the counties of Santa Cruz, San Luis Obispo, Santa Barbara, and Ventura. They contain from twelve to eighteen per cent. of bitumen and are easily pulverized when heated. They are used in most cases without other admixture for street paving, being rolled or tamped thoroughly while hot. Similar products are obtained from Utah and Kentucky, although that from Utah is often too rich in bitumen to be used for paving purposes without farther dilution with sand.

The production of asphaltum and bituminous rock in the United States for 1893 is given by the United States Geological Survey in "Mineral Resources of the United States for 1893," as 47,779 tons, of which California produced 42,650 tons, Utah 3,200 tons, and Kentucky 1,929 tons. For 1892 the production is given as 87,680 tons.

If we turn now to the question of the nature of the bitumen in these natural asphalts and malthas, we will find much to interest as well as to perplex us. Mention was made, in speaking of Boussingault's studies of the Bechelbronn mineral tar, of the distinction made by him of "petrolene" and "asphaltene," and of the definitions given those terms later by Kayser. We know now that there are no well-characterized compounds to which these names can be given but that the materials (obtained by fractional solution with different solvents) to which these names have been given are mixtures. In general, the mixture called "petrolene," and which is extracted from these natural asphalts by means of petroleum ether, acetone or common ethylic ether, is tough, viscid, and of great cementing quality, although soft; while that called "asphaltene," and which is extracted from the residue with hot turpentine, chloroform or carbon disulphide, is dry, friable and brittle; but the proportions of these extracted from one and the same asphalt, as has recently been very

clearly shown by Miss Laura A. Linton,* in an article on the "Technical Analysis of Asphaltum," will vary quite notably according to the choice of the solvent. It is, therefore, very obvious that the analyses before quoted of individual asphalts are, strictly speaking, not comparable, unless we know something as to the nature of the bitumen, of which the percentage is stated in a general way only. This may be illustrated by two analyses, for which I am indebted to a private communication of Dr. F. Salathé, chemist of the Standard Asphalt Company, of California. The first is of the crude black asphalt from Kern County, Cal., and which has been already mentioned; the second is of a light brown, friable, and non-cohesive rock, found near the surface of the asphalt vein:

	Total Bitumen.	Per Cent. of Total Bitumen Soluble in Acetone.	Per Cent. of Total Bitumen Left, Soluble in Chloroform.
Crude black asphalt	84·79	67·50	32·50
Crude brown asphalt	82·08	21·30	78·70

Two analyses from Miss Linton's article may be quoted also, as showing this difference in the nature of the total bitumen:

	Petrolene.	Asphaltene.	Non-bituminous Organic.	Mineral Matter.	Water.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Crude Trinidad asphalt	32·445	22·112	8·121	35·286	2·029
Crude Cuban asphalt	25·460	54·414	2·469	17·030	0·391

Again, if we turn to the ultimate analyses of the bitumen contained in the asphalts, we have many points of interest. The Trinidad and Bermudez, as well as the Syrian asphalts, contain notable quantities of sulphur more or less firmly combined with the hydrocarbons, while the California malthas and asphalts are nearly free from sulphur, but always contain nitrogen. Moreover, as was first observed by Dr. Salathé and confirmed by Prof. S. F. Peckham, this

*_Journal of the American Chem. Soc._, Dec., 1894, p. 817.

nitrogen is due to the presence of pyridine and quinoline bases, compounds which apparently indicate an animal origin for these bitumens. By studying the crude petroleums of California, Professor Peckham has found that the basic oils in their natural condition were combined with an exceedingly viscous, feebly acid, tar. Upon these observations he has founded an extremely interesting theory respecting the gradual changes whereby the California asphalts at least have been produced, and which I will give in his own words:*

"A number of facts observed indicate that all those forms of bitumen that have been least exposed to the action of atmospheric oxygen contain the largest proportion of basic oils. Analysis shows less nitrogen in the malthas, and still less in the asphaltums, than in the petroleums. It appears that the compound ethers or *esters* which exist in the native petroleums are decomposed with substitution of oxygen for nitrogen. This substitution I have made artificially. The result is the precipitation of the acid radical as a hydrate within the oil, in which it dissolves, producing a viscous tar. When this decomposition has proceeded so far that water in appreciable quantity becomes a constituent of the compound, the bitumen is no longer petroleum, but maltha. This water of hydration separates only when the maltha is heated to a comparatively high temperature. It will never separate by difference of specific gravity at comparatively low temperatures, but requires a temperature at which the hydrate is decomposed into a dense oil very much less viscous than the hydrate on the one hand and water on the other.

"As the change proceeds, the bitumen becomes solid asphaltum, and a new compound, that is found in maltha only in small quantity, if at all, appears. This is Boussingault's *asphaltene*, which was assumed by him to be an oxidized product in which oxygen was substituted for hydrogen. Recent experiments, not yet completed, indicate that asphaltene is not a simple substance, but that it may be resolved by suitable solvents into a compound containing oxygen and a compound that represents the original hydrocarbon, minus a portion of its hydrogen, by virtue of which it is no longer soluble in those fluids that dissolve the hydrocarbon in its original form."

There remains the practical side of the subject to be noted.

The uses of asphalt may be summarized as follows:

(1) As a varnish or paint.

(2) As the base of insulating compositions.

(3) As a waterproofing material.

(4) As a cement in ordinary building construction.

(5) As the cement in roofing and paving compositions.

**Amer. Jour. of Science*, Sept. 1894, p. 254.

(It is stated that fully ninety-five per cent. of the asphalt used is for the last-named purpose.)

For the manufacture of asphalt varnish or paint, the asphalts rich in bitumen (like gilsonite) are used, the bitumen being partly dissolved by admixture with oil of turpentine and linseed oil. In this way a so-called Japan varnish is obtained for the process of japanning metals. The asphalt varnish may also have other resins (like shellac) added in order to give greater flexibility and toughness.

For the manufacture of insulating compounds the asphalt is usually tempered with wax tailings and other petroleum products to give the mixture the proper consistency; the exact composition of the mixtures being, however, carefully kept secret by the manufacturers.

For waterproofing the foundations of buildings, and as a protection against moisture in cellars, etc., a refined maltha or melted asphaltum is often used, being painted on the masonry or timber, or bricks are dipped in it before being set in position. For lining reservoirs, irrigating canals and ditches, an asphalt cement similar to that used for paving is frequently used. In this case, as has been shown in practice, a natural asphalt with a proper proportion of bitumen and mineral matter, or a natural asphalt tempered with a maltha or so-called "liquid asphalt," will yield a more homogeneous and water-resisting coating material than an asphalt tempered with either coal tar or petroleum residuums.

For other forms of construction, especially for paving sidewalks, stable-yards, open areas and flooring in exposed positions, as upon flat enclosed roofs of large buildings, asphalt mastic is used. The basis of this is usually one of the natural asphaltic limestones, such as Seyssel or Neufchatel asphalt.

The rock, having been powdered, is put in round kettles in which about eight per cent. of its weight of refined Trinidad asphalt has been previously melted. It is thoroughly mixed with this at about 280° F. for several hours, and is then run into moulds, where it is formed into square,

hexagonal or round blocks, of about fifty to sixty pounds weight. When the mastic is to be used, it is again melted with refined Trinidad asphalt, in the proportions of about seven pounds of asphalt to 100 pounds of the mastic, and sand or fine gravel is added gradually up to sixty pounds, according to the use to which the mixture is to be put. This mixture, known as "gritted mastic," is spread while hot, rubbed smooth and allowed to cool. When cold it is slightly pliable and thoroughly waterproof.

The last-named application of asphalt, viz.: for roofing and paving construction, as before stated, is by far the most important of all the others. As applied to roadway or street-paving, we have two entirely distinct methods to note. The asphaltic limestones such as are found in Europe, and asphaltic sandstone such as is found in California, require merely to be crushed, heated to from 275° F. to 300° F., and hauled to the streets and spread uniformly while still hot. It is then tamped and rolled with hot instruments. Asphalt pavements of this kind are in general use in Paris, London, Berlin and other European cities. Roadways made from bituminous limestone are said to become polished by wear and to become slippery in foggy and drizzling weather. In California, where bituminous sandstone is used, they are said to wear well, except that they soften rather too much in warm weather.

The other form of asphalt paving construction, used most largely in this country, is that in which an asphalt cement is first made by taking a hard but relatively pure asphalt and tempering it with some oily or bituminous liquid. This cement, in the proportion of ten to sixteen parts, is then mixed at a temperature of about 300° F. with from eighty-four to ninety parts of clean sand and powdered limestone, and the mixture applied with no more loss of heat than necessarily follows its transportation to the streets in covered carts.

While this general statement as to the nature of an asphalt paving composition may be taken as covering the subject broadly, many points of the greatest importance come in to determine whether a given composition will be

a satisfactory one or otherwise. The asphalt should be one with a high percentage of so-called petrolene as compared with asphaltene; the oily or bituminous liquid above referred to should be one that will make a satisfactory and durable blending with the asphalt, and the proportions of tempering liquid and asphalt which go to make up the cement should be chosen with reference to climate and the character of the traffic that is likely to pass over the street.

The analyses quoted in this lecture will show how asphalts may differ in the first respect. With regard to the nature of the tempering liquid, I may say that coal tar was at one time used, but has been almost universally rejected, as not making a satisfactory or durable blending material, the mixture having been found to disintegrate under atmospheric influences. Petroleum residuums are now almost universally used in the Eastern States, while malthas, or natural "liquid asphalts," so-called, are used on the Pacific Coast and in Western States. I am satisfied, on both theoretical and experimental grounds,* that the last-named tempering materials are to be preferred. The time allowed for an illustrated lecture on a broad, general subject of the nature of this will not allow me to go into a discussion of this question here. Thanking my audience for their kind attention, I will therefore bring my account of asphalts to an end.

RAINFALL AND TYPHOID FEVER.

By Wm. P. Mason.

The first, or at least one of the first, to call attention to the relation between water and typhoid fever was Dr. Michel, of Chaumont, France. In 1855 he observed that typhoid, which was epidemic in the above place, varied in number of cases and in intensity inversely as the quantity of water in the public wells.

Pettenkoffer, of Munich, about the same time, undertook extended observations upon variations in the height of

* *Paving and Municipal Engineering*, September, 1894, p. 118.

ground water, and, a little later, relationship was shown between these variations and the occurrence of typhoid fever.

Those who hold with Pettenkoffer, claim that the elements of the disease readily multiply in the soil, and are driven therefrom along with the ground air, upon the rising of the water level at the time of the autumnal rains.

Latham, in speaking upon this point, says:

"No great variation in the vertical rise and fall of sub-soil water is the healthier condition. The ground always contains air, and, as the ground water sinks, air is drawn in to supply its place. After long dry weather, the air of the soil is thus laden with products of decomposition. A rain now occurring, the ground air is displaced, and since said rain is liable to seal the surface, the tendency of the air is to escape laterally, *i. e.*, into cellars. Dry summers invariably mark unhealthy years. Typhoid fever occurs after the autumn rains.

"All the great epidemics of typhoid have occurred in years when the ground water was especially low, and after a slight rise in the same."

Pettenkoffer's "ground-air theory" is not gaining the majority of supporters, a more reasonable view being, that as the water surface lowers in a well, the base of the cone of drainage, whose apex is at that surface, is extended, and consequently, more widely situated points of pollution are embraced within its influence.

Perhaps the most exhaustive examination of the relation of the height of ground water to the prevalence of typhoid that has been made in America, is to be found in the work of the State Board of Health of Michigan.

Observations have been made by that Board during a period of many years, and the results, graphically shown herewith, indicate in a very marked manner that increase of typhoid and lowness of water in wells move in practically the same curve of variation.

So convinced were the Michigan authorities of the truth of this proposition, that they issued, during the past autumn, a circular of warning, which is here quoted in part:

"*Beware! Unusual Danger now from Typhoid Fever, because of Drought.*

"The water in the representative well near the center of the State, last September, was three inches more than the average of previous years; this year it is four inches less than the average.

"For the second week in September, typhoid fever is reported from thirteen places more this year than last year, etc., etc."

The Michigan statistics go, further on, to show that in October, 1894, the water in the standard well stood eleven inches lower than in October, 1893, and seven inches lower than the October average for the eight years, 1886–1893.

For September, 1894, typhoid fever was reported from 121 places in the State, an increase of forty-six places over the report for September, 1893.

For October, 1894, typhoid was present at 165 places, as against 109 for the same month of 1893.

For October, 1894, the prevalence of the disease is forty-four per cent. above the October average for the eight years, 1886–1893.

During the three months of September, October and November, 1894, the ground water of Michigan grew constantly lower. It is difficult to see just how these data could be made to fit the "ground-air" theory of Pettenkoffer or Latham as a cause of typhoid fever; for such theory calls for sudden rise in ground-water level.

The precipitation data for Michigan are:

	1893.	*1894*	*Normal.*
January	2·55	1·88	2·18
February	2·65	1·81	2·67
March	2·39	2·16	2·32
April	4·43	2·28	2·44
May	2·79	5·79	3·52
June	3·26	2·82	3·91
July	2·74	1·40	3·09
August	1·19	0·49	3·04
September	2·34	3·42	3·00
October	3·67	2·86	3·05
November	2·90	1·76	3·02
December	3·64	1·33	2·51

It has been the continued experience in Michigan that typhoid is coincident with low ground water, as is illustrated graphically herewith, and is not dependent upon sudden rise in the same. An interesting exception to this rule has been noted, occurring during the season of heavy frost, when surface pollution is prevented from reaching the subsoil.

Dr. Henry B. Baker, Secretary of the Michigan State Board of Health, to whom I am indebted for much information, also furnished me with this table:

EXHIBITING THE AVERAGE TOTAL ANNUAL RAINFALL AT STATIONS IN MICHIGAN THE SAME FOR LANSING, THE INCHES OF EARTH ABOVE THE GROUND WATER AT LANSING, THE INCHES OF WATER IN AN UNDISTURBED WELL AT LANSING, AND THE REPORTED SICKNESS, FROM TYPHOID FEVER IN MICHIGAN, AS INDICATED BY THE PER CENT. OF ALL THE WEEKLY CARD-REPORTS WHICH STATED THE PRESENCE OF TYPHOID FEVER DURING THE SEVEN YEARS AND EACH OF THE SEVEN YEARS, 1885–91:

Year, and Period of Years.	Average Total Annual Rainfall at Stations in Michigan, in Inches.	Total Annual Rainfall at Lansing, in Inches.	Inches of Earth above the Ground Water at Lansing.	Inches of Water in an Unused Well at Lansing.	Ground Water Higher (+) or Lower (—) than the Seven Years' Average in Inches.	Average Per Cent. of all Weekly Card-reports Stating the Presence of Typhoid Fever.	More (+) or Less (—) Sickness from Typhoid Fever than the Seven Years' Average.
Av. 7 years, 1885–91 . .	31·06	29·45	293	31	=	9	=
1885	35·82	34·51	284	40	+ 9	8	— 1
1886	32·16	29·52	281	42	+ 11	8	— 1
1887	29·82	30·08	290	34	+ 3	10	+ 1
1888	29·55	25·76	294	29	— 2	10	+ 1
1889	28·18	23·28	304	19	— 12	10	+ 1
1890	30·20	33·96	300	28	— 3	8	— 1
1891	31·66	29·05	301	23	— 8	11	+ 2

We do not possess in New York so complete records as to the condition of the ground water as they have in Michigan; but the rainfall, upon which ground water depends, is on record, and the reports show that more than the average amount of rain fell in New York during the autumn past, following, as it did, an exceedingly dry summer.

If typhoid fever bears relation to sudden rise in level of ground water, as has been held, rather than to the prolonged low state of such level, as is taught in Michigan, then surely the autumn of 1894 was a favorable time for a marked outbreak of the disease in the State of New York, but no such condition is reported by the sanitary authorities.

Just how the year of 1894 compared, in the matters of typhoid and rainfall, with 1893 and 1891, may be seen from the accompanying charts.

The above years were chosen for comparison because the summer of 1893 was very wet, and because the entire year of 1891 was especially noted for prevalence of typhoid fever.

These curves are very irregular, and suggest in places relation between low rainfall and prevalence of the disease; but the remarkable concordance exhibited in the Michigan chart is here sought in vain.

New York does not stand alone in its failure to accord with the Michigan rule, as is seen from the following Connecticut statistics:

	1894.		1893.		Normal.	
	Rainfall in Inches.	Deaths Typhoid.	Rainfall in Inches.	Deaths Typhoid.	Rainfall in Inches.	Deaths Typhoid.
July	2·40	15	1·89	18	4·99	14·8
August	1·70	38	4·86	14	5·17	32·8
September	4·63	38	2·24	37	3·76	41·4
October	6·11	32	4·75	49	3·90	42·6
November	4·23	37	2·56	35	3·90	40·2

As elsewhere, so in Connecticut, the summer of 1894 was very dry, and very heavy rains fell in the autumn, yet the autumn death rate was below the normal. If any weight is to be attached to the *sudden rise* in ground water, surely here was an opportunity for its exhibition; but the rise in water level was followed by no increase in typhoid.

Minnesota was also an apparent exception to the Michigan rule, as we see from the following:

	1894.		Normal.	
	Rainfall in Inches.	Deaths Typhoid.	Rainfall in Inches.	Deaths Typhoid.
August	1·22	39	2·80	43
September	2·04	42	2·04	67
October	3·37	47	1·55	87
November	0·54	30	0·69	62

This State presents a refutation of the "ground air" theory, for there was certainly a "sudden rise" in level of the ground water, without corresponding increase of typhoid; but there is no real exception here to the "Michigan rule," for it will be remembered that the said rule calls for marked lowness of ground water, and we notice that the autumn rainfall was above the normal in this State.

Among the other States heard from, the majority unquestionably fall under the Michigan rule. Definite information regarding mortuary statistics, was, in the cases of many States, impossible to secure, and only such expressions as "considerable typhoid," "largely increased typhoid" were obtainable. No statistics whatever are kept in certain States, and from them no results could be recorded.

The health department of Iowa writes, under date of December 17, 1894:

"There is greatly increased typhoid fever in this State. Scarcely a town or township is exempt."

The Iowa rainfall was:

	1894.	*Normal.*
August	1·58	3·60
September	3·57	3·70
October	2·67	2·85

Here again is noticed the probable low condition of ground water, and the application of the Michigan rule.

The Board of Health of Ohio writes: "We have noticed a very decided increase of typhoid fever in our State during the past autumn. It has also been noticeable that the increase has been almost wholly in our small villages, where wells are used for water supply."

The Ohio rainfall was:

	1894.	*Normal.*
August	1·67	3·04
September	3·31	2·94
October	2·01	2·57
November	2·17	2·99

This was also an instance of prolonged low water, with results following the rule.

In Pennsylvania, the records show large amount of typhoid present during the past autumn, with rainfall as follows:

	1894.	*Normal.*
August	1·84	4·90
September	6·30	3·72
October	4·26	3·48
November	2·50	3·33

A word is necessary here regarding the great precipitation for September. It will be remembered that, on the eighth of that month, an exceedingly violent storm swept over the eastern coast of the United States, with very heavy rainfall.

A great portion of this rain found its way directly to the streams and water-ways, and the ground water received but little reinforcement.

In Maryland "there has been a decided increase in the number of typhoid fever cases during the past six months (*i. e.* June to December) in all parts of the State. The rate of mortality has been low."

The rainfall was:

	1894.	*Normal.*
August	1·55	4·76
September	2·45	3·87
October	3·17	3·76
November	3·65	2·78

Low condition of ground water is here very apparent, and the State falls under the rule.

In Wisconsin "there is thought to have been a slight increase of typhoid in the State during the past autumn but not very marked."

The Wisconsin rainfall was:

	1894.	*1893.*
August	0·78	2·03
September	3·58	2·32
October	3·04	2·49
November	1·93	1·33

Comparison with the normal for this State is not possible from the data in my possession. It will be noticed, however, that the autumn was probably wet, and the typhoid was practically normal.

I do not possess the normal values for Massachusetts, but a comparison of 1894 with the previous year stands as follows:

	1894.		*1893.*	
	Typhoid.	*Rain.*	*Typhoid.*	*Rain.*
August	27	1·75	40	5·22
September	83	3·46	60	2·38
October	60	4·96	116	4·01
November	58	3·36	104	2·17

Evidently, Massachusetts is not to be rated as in accord with the Michigan rule.

In Indiana, so far as the Board of Health has been advised, "there has been about the usual amount of typhoid fever, following dry weather, more than there is after a season of plentiful rainfall."

The Western States, so far as heard from, are thus seen to follow, as a class, what has been styled the "Michigan rule," with the apparent exception of Minnesota; but it has been shown that this is really no exception at all in view of the more than normal rainfall. Now, what reasonable explanation can be given for the failure of New York, Connecticut and Massachusetts to accord with the rule?

While not wishing to dogmatize upon manifestly scanty data, the suggestion is offered that, so far as these three States are concerned, larger shares of their populations derive their drinking water from more or less carefully selected sources of public supply, and are consequently less exposed to danger from the local contamination of private wells.

Whether the exhaustive study of facts does, or does not,

support the view that the relation of typhoid fever and rainfall, so far as ground water is concerned, deals with the question of low ground water, rather than with fluctuations in its vertical height, it admits of ready illustration that marked relationship certainly exists between this disease and the sudden influx of storm waters, which flood the polluted channels of some smaller rivers.

A recent publication of the London Local Government Board deals with this question most thoroughly, in an inquiry concerning a typhoid fever outbreak occurring in the valley of the river Tees.

The Tees is a small stream of northern England, about seventy miles long, and navigable for about four miles from its mouth.

Many important towns upon its banks pump from this river, and a goodly number of the inhabitants of the sanitary district use its waters for domestic purposes.

In many places, especially in the towns, it receives all sorts of polluting additions, which are carried on by the current to intakes below. During dry weather, the stream recedes considerably, leaving uncovered its rocky foreshores (shown in the accompanying views), which receive and accumulate filth of every variety, and retain the same until, by reason of heavy rain, the river suddenly rises and sweeps the refuse downward towards the towns nearer the sea.

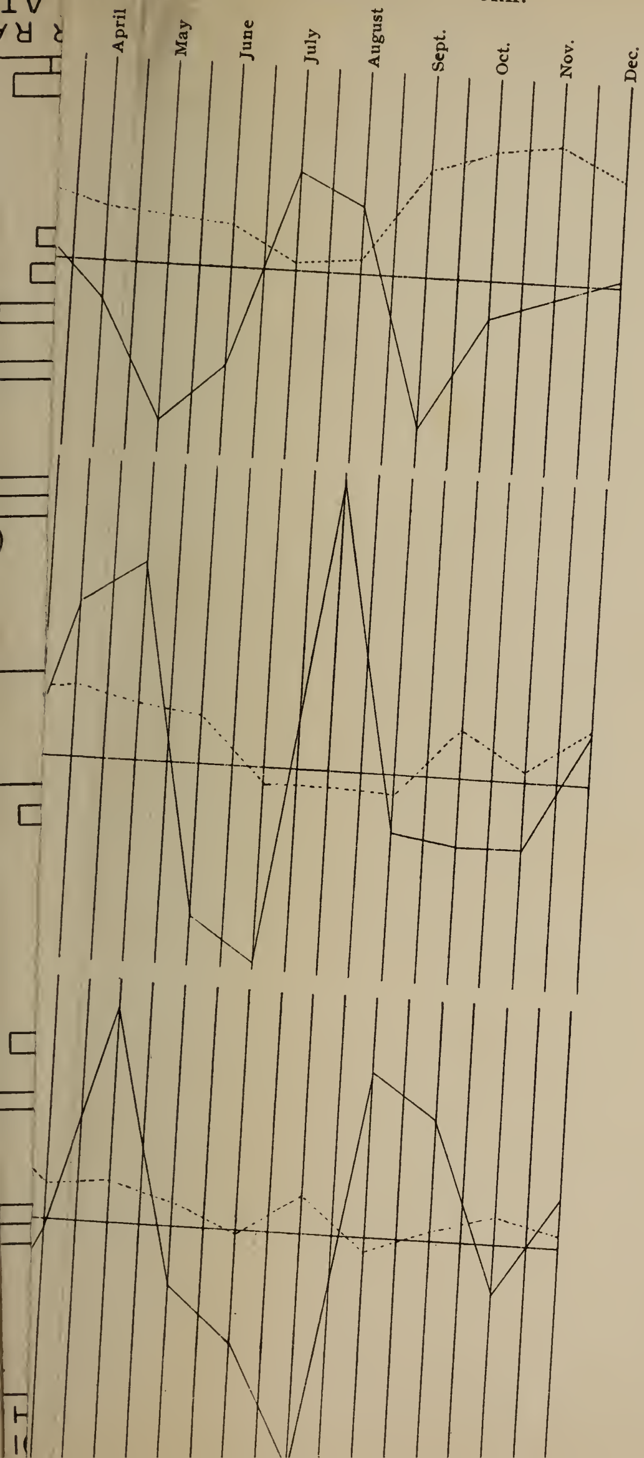
The result produced upon the thoughtless public, of such an extra and concentrated dose of sewage material added to their water supply, is best shown graphically by the accompanying chart, where it will be observed that increase of rainfall is followed by increase in cases of typhoid fever, among the 219,435 persons using the Tees water, after an interval corresponding to the incubation period of the disease, while no appreciable result is noticed among 284,181 people of the same district, using other sources of supply.

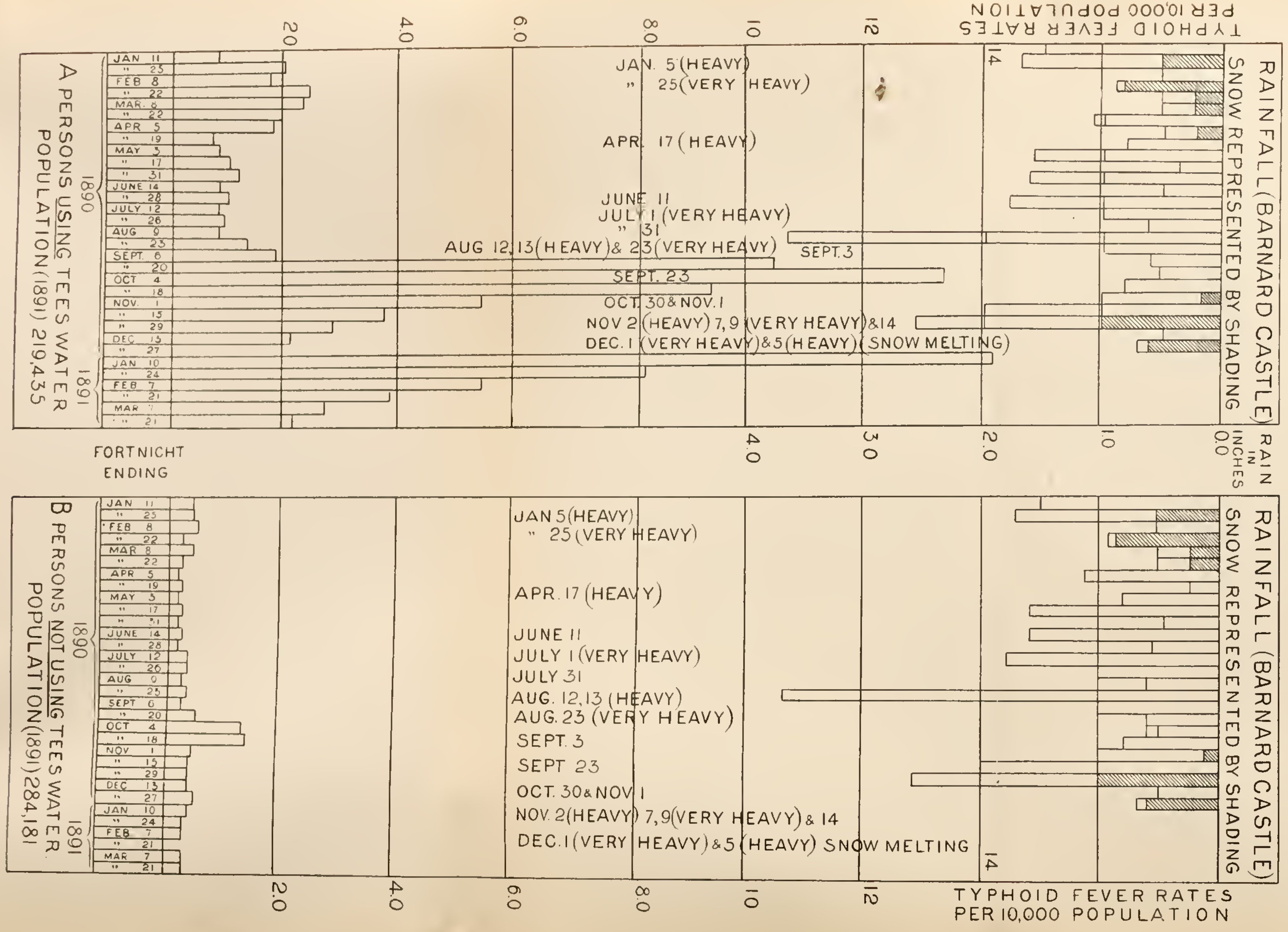
The "typhoid rates" given in the chart are "cases," not "deaths."

RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y., April, 1895.

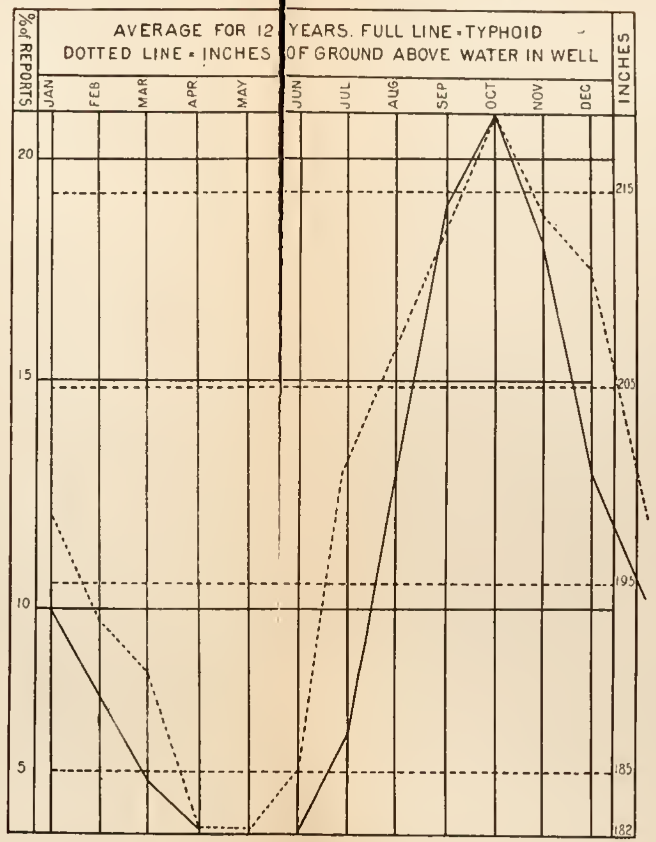
(*Mason—Rainfall and Typhoid Fever.*)

…ONS FROM NORMAL—STATE OF NEW YORK.

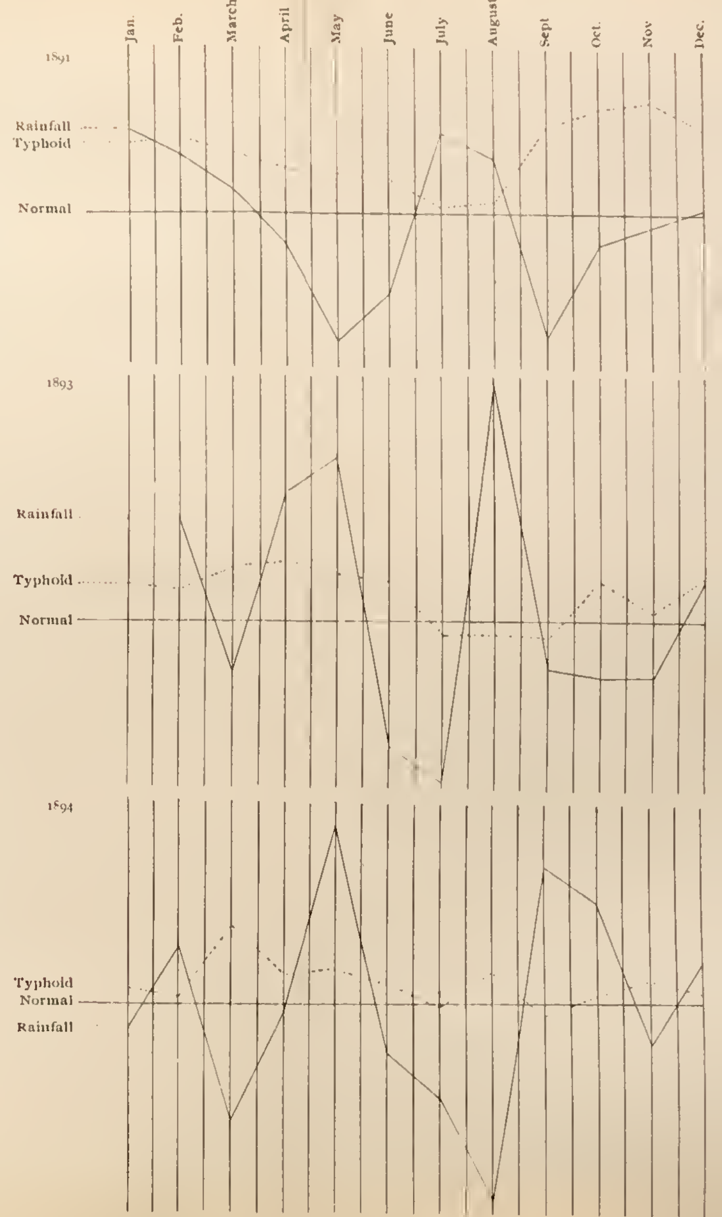




Low Water in Wells and Typhoid Fever—Michigan.



Variations from Normal—State of New York.



CHEMICAL SECTION.

Stated Meeting of June 18, 1895.

MR. J. H. EASTWICK in the Chair.

INVESTIGATION OF UTAH GILSONITE, A VARIETY OF ASPHALT.

BY WM. C. DAY.

A study of the literature of asphalt and allied bitumens reveals but few publications which throw light upon the true nature of these bodies, or of the classes of hydrocarbons which, in intimate mixture, appear to constitute them.

Boussingault* studied the bitumen of Bechelbronn with reference to the action of solvents upon it, and also the products resulting from distillation under the ordinary atmospheric pressure. By heating the material in an oil bath to the temperature 230° C. for a long time (*i. e.*, a number of days), he obtained a distillate to which he gave the name "petrolene," while the undistilled residue he called "asphaltene." The distilled "petrolene" showed a brown color, which was regarded as due to asphaltene mechanically carried over. After drying over calcium chloride, the petrolene was rectified and described then as being in a state of purity, having a pale yellow color, and an odor like bitumen. Its density was given as 0·891 at 21°.C., and its boiling point 280° C. It was slightly soluble in alcohol, and much more so in ether. In a note he says that it is impossible to determine the proportions of asphaltene and petrolene by the heating method, since the petrolene oxidizes and becomes converted into asphaltene. On the basis of combustions of asphalt purified by ether, he gives the proportions of asphaltene and petrolene as 85·4 per cent. and 14·6 per cent., respectively.

Ann. d. Ch. et de Phys., II, **64**, 141.

An elementary analysis of the asphalt gave the following figures:

	Per Cent.
C.	85·90
H.	11·25
O.	2·85
	100·00

It is noteworthy that in this analysis no mention is made of nitrogen or sulphur.

Völckel* investigated the mineral tar from Dax. Of this he found 50 per cent. soluble in ether. The ethereal solution becomes turbid upon the addition of absolute alcohol, precipitating a blackish-brown mass. Using a large excess of alcohol, only a small amount of oil remains undissolved in the mixture of alcohol and ether. The material left behind on evaporating the ethereal solution he regards as identical with the asphaltene of Boussingault.

By distilling asphalt rock in iron cylinders a peculiar volatile oil is obtained, having an odor like mineral tar, and a faint taste. It is insoluble in water and alcohol, but readily soluble in ether. The distillate, when distilled by itself, or with water, always shows a yellowish color. This yellow color is ascribed to a small amount of yellow oil, which, in the distillation of a number of resins, particularly copal, is obtained in greater quantity. The raw asphalt oil was shaken with a concentrated solution of caustic potash, then distilled with steam, dried over calcium chloride, and finally distilled by itself from a retort provided with a thermometer. The oil begins to boil at 90° C., but the boiling point rapidly rises to 120° C. The greater part of the oil distils at 200° C., a smaller part from 200° to 250°. At the latter temperature there remains a small quantity of thick, strongly colored oil as a residue.

The following quantitative results are given. The portion boiling between 90° and 200° showed, at 15° C., a specific gravity of 0·817, and, by combustion, the following percentage composition:

Ann. Ch. Pharm.*, **88, 139.

	Per Cent.
C.	87·37
H.	11·65
O.	0·98
	100·00

That boiling between 200° and 250° showed a specific gravity of 0·868, and the following percentage composition:

	Per Cent.
C.	87·55
H.	11·56
O.	0 89
	100·00

The author calls attention to the fact that asphalt oil has exactly the same composition as amber oil, obtained by distilling amber, and further states that these oils are also similar in general conduct.

By the action of dilute nitric acid, asphalt oil is colored brown at ordinary temperatures; by heating it changes into a yellow gummy mass, which smells like musk and oil of bitter almonds. Concentrated nitric acid works in the same way, but more violently. Concentrated sulphuric acid dissolves, with evolution of heat, a part of the asphalt oil, while another part collects upon the surface of the thick, red-colored sulphuric acid solution. The separated oil was again treated with sulphuric acid, and then with alkali, and finally distilled with steam. The distillate thus obtained possesses a faint, pleasant odor, entirely different from the oil not treated with sulphuric acid. After dehydration by long contact with chloride of calcium, the oil was distilled; it began to boil at 90° C., but very little went over below 120°. The following fractions were separated: 90°–120°; 120°–150°; 150°–180°; 180°–200°; 200°–220°; 220°–250°. All these fractions were analyzed with practically the same results—C., 87·50 per cent.; H., 12·50 per cent. The part of asphalt oil not taken up by sulphuric acid shows, therefore, the formula $N(C_6H_5)$. These oils are insoluble in water, but easily soluble in alcohol and ether. They are only slightly attacked by concentrated sulphuric acid, and do not dissolve in concentrated nitric acid. By heating with nitric acid,

only a small part is changed into a heavy yellow oil, which, by distillation with steam, is obtained colorless. In chemical constitution these oils agree with the volatile oils which separate on treating amber oil with concentrated sulphuric acid.

R. Kayser,* in 1879, published the results of an investigation upon the products obtained from a number of asphalts of different sources, by the action of the solvents alcohol and ether, and also of products obtained by destructive distillation of the original asphalts. Kayser made quite a large number of elementary analyses of asphalts, and of products obtained from them by the action of alcohol and ether, and by destructive distillation. In his analyses were included determinations of carbon, hydrogen, sulphur, nitrogen and ash. In the older investigations, the presence of sulphur appears to have been overlooked or ignored. In many of them nitrogen, also, was undetermined.

In Kayser's paper, formulæ for the products analyzed were proposed in accordance with the requirements of the analytical results. Bodies "of constant boiling point" were obtained by fractional distillation of the products obtained from the destructive distillation of the original material. The asphalts included in this investigation were taken from the following sources: from Syria, Trinidad, Bechelbronn, Maracaibo and Barbadoes. The following table shows the results obtained by Kayser in his elementary analyses of the various asphalts studied by him:

ANALYSES OF VARIOUS ASPHALTS BY KAYSER.

	Syria. Per Cent.	*Trinidad.* Per Cent.	*Bechelbronn.* Per Cent.	*Maracaibo.* Per Cent.	*Barbadoes.* Per Cent.
Carbon	80·00	78·80	86·60	81·65	87·04
Hydrogen	9·00	9·30	11·40	9·59	9·56
Sulphur	10·00	10·00	1·40	8·03	2·67
Ash	0·60	0·50	0·50	0·34	0·24
Nitrogen . . .	0·40	1·40	0·30	—	—
Oxygen	—	—	0·40	—	—
	100·00	100·00	100·60	99·61	99·51

* *Mittheilung aus dem Laboratorium des Bayerischen Gewerbemuseums zu Nürnberg.*

In the first three cases the figures are the averages of a number of well-agreeing determinations; in the two others (Maracaibo and Barbadoes), the figures are the results of single determinations.

Although Kayser claims to have obtained pure substances as the result of fractional distillation of the Syrian asphalt oil, and gives to these bodies definite formulæ as the results of elementary analysis, the evidence given by him of their purity is hardly satisfactory, since he does not, in any case, give the exact range of boiling point, but gives the boiling points in round numbers. Furthermore, he describes a number of them as yellow and brownish-yellow in color, the first one only (boiling at 96°) being described as water-white. The following table gives the formulæ ascribed by Kayser to the ten fractions obtained in the distillation of Syrian asphalt oil:

	Boiling Point.	*Formula.*	*General Formula.*
I.	96° C.	$C_{12}H_{24}S$	$C_n H_{2n}$ S.
II.	158° C.	$C_{39}H_{70}S$	$C_n H_{2n-8}$ S.
III.	170° C.	$C_{38}H_{66}S$	$C_n H_{2n-10}$ S.
IV.	188° C.	$C_{40}H_{68}S$	$C_n H_{2n-12}$ S.
V.	221° C.	$C_{36}H_{58}S$	$C_n H_{2n-14}$ S.
VI.	225° C.	$C_{35}H_{58}S$	$C_n H_{2n-12}$ S.
VII.	229° C.	$C_{36}H_{58}S$	$C_n H_{2n-14}$ S.
VIII.	233° C.	$C_{36}H_{56}S$	$C_n H_{2n-16}$ S.
IX.	240° C.	$C_{36}H_{56}S$	$C_n H_{2n-16}$ S.
X.	265° C.	$C_{36}H_{54}S$	$C_n H_{2n-18}$ S.

Without further and more satisfactory evidence the conclusions here arrived at by Kayser seem unwarranted.

Although there are in print many articles of value on the commercial applications of asphalt, and some giving the results of elementary analysis, I have failed to find any publications other than the ones already considered, and an important paper by Peckham, to be referred to later, which throw light upon the real nature of the asphalts, or which definitely describe pure products obtained from them.

The present investigation of gilsonite had for its object the isolation of such single hydrocarbons, or classes of hydrocarbons or their derivatives, as would give some information as to the nature of the material itself.

Although this object has not yet been fully attained, such progress toward that end has been made as to indicate that definite results are near at hand. As the work must be interrupted for a few months, I have thought best to give an account of the results thus far obtained.

Gilsonite* is a black, brittle material, pulverizing readily to a dark brown powder, which is inclined to stick to the sides of the mortar when finely divided. It is lighter than water, and entirely soluble in carbon bisulphide.

Absolute alcohol dissolves 54·6 per cent., if repeatedly treated with the hot liquid until no further action is noticeable. The following figures, showing the solubility in alcohol were obtained: 2·2298 grams of gilsonite gave 1·2178 grams of insoluble residue, while the dissolved matter weighed 1·01 grams.

Ether does not dissolve gilsonite entirely, as shown by two successive treatments of a small quanity of gilsonite with a large excess of ether; the solution obtained is red in color, with a greenish fluorescence. Absolute alcohol added to the ether solution gives a precipitate. Petroleum ether, glacial acetic acid and chloroform are partial solvents.

The residue obtained by evaporating the petroleum ether solution is black in color, hard, brittle and differs markedly from the material soluble in alcohol. It resembles the original gilsonite quite closely. Only a small percentage of gilsonite remains undissolved in petroleum ether after twenty-eight successive treatments with the solvent. This insoluble residue is black and very easily pulverized.

The residue obtained by evaporating the alcoholic solution is reddish-brown in color, solid at ordinary temperatures, but soft enough to be easily cut with the finger nail. On being heated on the water bath it becomes softer, and at 100° C. is liquid enough to flow.

The residue, insoluble in alcohol, is a black, brittle substance, becoming brownish in color on pulverizing, and resembling in appearance the original gilsonite.

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* The material upon which I have worked was kindly furnished by the Gilson Asphaltum Company, of St. Louis, Mo.—W. C. D.

ANALYSIS.

To determine the volatile matter, fixed residue and ash, weighed quantities of gilsonite were heated in a platinum crucible, first covered, and afterwards, when all volatile matter had been expelled, uncovered. 0·2391 gram gilsonite gave 0·1041 gram fixed residue, and 0·0003 gram ash. These figures show that gilsonite yields:

	Per Cent.
Volatile matter	56·46
Fixed residue	43·43
Ash	0·10
	99·99

Working on a larger scale, and distilling a weighed quantity of gilsonite from a retort, the following result was obtained: 136·1 grams of gilsonite gave 76·1 grams of distillate. The percentage of volatile matter is thus 55·9. Comparing this result with that above it is evident that all the volatile matter is condensable.

Elementary Analysis.—Combustions were made with lead chromate in a current of oxygen:

(I) 0·6160 gram gilsonite gave 1·9872 grams CO_2, and 0·55615 gram H_2O.
(II) 0·4715 gram gilsonite gave 1·5318 grams CO_2, and 0·4195 gram H_2O.

Percentages of carbon and hydrogen found:

	I.	II.
Carbon	87·99	88·61
Hydrogen	10·03	9·89

The determination of sulphur in gilsonite proved to be a matter of some difficulty, and, before success was finally attained, all the various methods of determining sulphur in organic compounds were tried.

Sauer's method of burning in oxygen and passing the products of combustion into a hydrochloric acid solution of bromine was found inapplicable, on account of the great difficulty of securing steady vaporization of the volatile constituents of the gilsonite. Owing to the tendency which, at certain stages of its distillation, gilsonite shows to foam or volatilize very rapidly, some of this vapor almost inevitably escapes combustion in the oxygen. The writer has

used this method with success in the case of volatile petroleums, and is, therefore, sure that the difficulties which stand in the way of its application to gilsonite are inherent in the substance, as above described.

Good results in the determination of sulphur were finally secured by a combination of the Carius method of oxidizing with nitric acid in an open vessel, and then heating the unoxidized solid material with magnesia in a platinum crucible, as recommended by Eschka in determining sulphur in coals. The sulphur is finally weighed as $BaSO_4$. When gilsonite is treated with a large excess of concentrated nitric acid, under the influence of heat in an open vessel, brown fumes are abundantly given off, and, after a time, the gilsonite entirely dissolves, giving a dark red solution, which becomes constantly lighter as the heating is continued. If at the point when the gilsonite is just completely dissolved the solution is poured into cold water, a reddish-brown precipitate, closely resembling ferric hydroxide is immediately thrown down. This precipitate contains practically all the sulphur, only traces having been converted into sulphuric acid by the oxidizing action of the nitric acid. This precipitate was washed with water, dried, then mixed with magnesia, and the sulphur determined as already described.

(I) 1·30215 grams gilsonite gave 0·1231 gram $BaSO_4$.
(II) 0·9581 gram gilsonite gave 0·09414 gram $BaSO_4$.

Percentage of sulphur from I	1·29
Percentage of sulphur from II	1·34

The results obtained by other methods did not show sufficiently close agreement, ranging, however, only between the limits 0·93 and 1·59 per cent.

The percentage composition of gilsonite, therefore, appears to be:

	Per Cent.
Carbon	88·30
Hydrogen	9·96
Sulphur	1·32
Ash	0·10
Oxygen and Nitrogen (undetermined)	0·32
	100·00

DRY DISTILLATION OF GILSONITE.

Before undertaking the direct distillation, some of the finely powdered gilsonite was subjected to distillation with steam. The receiver showed a slight film of colorless oil, of pleasant odor, floating upon the water. The amount of oil was so small that nothing further could be done with it.

In the dry distillation the material was first distilled from a tubulated retort provided with a thermometer, the bulb of which was in the liquid. Distillation began at 150° C., but very little came over; the temperature rose quite rapidly; but before the distillation was fairly under way, the thermometer had to be removed as the temperature rose above 300° C. The first drops of oil coming over were light yellow; this color became darker as the distillation progressed. The operation could not be carried to completion on account of the softening of the glass, although with a hard glass retort on another occasion the distillation was continued until nothing but coke was left. Glass retorts were finally replaced by one made of six-inch iron pipe, capped at both ends, and connected with a smaller pipe to serve as condenser. Energetic foaming takes place at two different stages; this fact necessitates the greatest care in the regulation of the heating flame, and it is a very difficult matter to avoid the carrying over of undistilled matter, particularly when using an iron retort. Toward the end of the distillation ammonia is quite freely evolved. The distillate is lighter than water, is of a reddish-brown color, and shows a greenish fluorescence; the odor is highly unpleasant. It was distilled with steam. This treatment separates the oil into a portion readily volatile with water vapor, and of a yellow color, and a thick, black, tarry-looking oil which remains in the distilling flask.

Oil Volatile with Water Vapor.—The volatile portion was distilled again with steam, becoming, as a result, much lighter in color, but on standing it changes from a lemon-yellow, to a reddish tint. The odor is suggestive of sulphur compounds. The oil, after drying over calcium chloride, was next treated with concentrated sulphuric acid, the two liquids being placed in a round-bottomed flask, and thoroughly shaken

together; the acid became very dark red, almost black in color, sulphur dioxide was freely evolved and so much heat was produced that the flask became too hot to handle. This treatment, using afterward fuming sulphuric acid instead of ordinary concentrated acid, was repeated until, after twenty-five or thirty treatments with fresh acid each time, no further action could be detected. The oil at this stage, after washing with alkali and water, and drying over calcium chloride, is water-white, of a pleasant odor, much like that of highly refined petroleum after repeated distillations over metallic sodium.

Concentrated nitric acid and a mixture of concentrated nitric and fuming sulphuric acids have no effect upon it, even after prolonged heating on the water bath. It dissolves bromine, but without chemical action or evolution of hydrobromic acid. The washed and dried oil, subjected to distillation, begins to boil at 125°, and, with the exception of a few remaining drops, is entirely distilled when the temperature reaches 263° C. After standing for six months over calcium chloride, the oil is still perfectly water-white. The total bulk of the oil so treated with sulphuric acid is very much reduced; perhaps less than 10 per cent. survives the action of the acid. The chemical inertness of this oil shows that it belongs to the paraffin series. Judging from the regular and uniform rise of temperature in distilling, the oil is just as complicated a mixture of different hydrocarbons as is highly refined petroleum.

The sulphuric acid used in treating this oil was preserved for subsequent investigation. The action of sulphuric acid was apparently largely of an oxidizing character, judging from the copious evolution of sulphur dioxide, which was so vigorous at times that the liquid almost foamed out of the flask. A part of this spent acid was diluted with water; a milky turbidity was produced, and, on warming and allowing to stand, a green oil rose to the surface. This oil has an odor something like that of pennyroyal. The dilute acid was neutralized with precipitated chalk, the resulting gypsum filtered off, and the solution evaporated. A sticky, gummy substance, separated when nearly all the water was

driven off; when perfectly dry the material became a pulverisable solid, light in color, deliquescent, very easily soluble in water, and entirely insoluble in ether.

The oil which rises to the surface on diluting the spent sulphuric acid becomes, on standing, a thick, tenacious black tar, of such consistency that, on being stirred, it takes a long time to spread again over the surface of the water. This was skimmed off and heated with water on the water bath; it seems to dissolve entirely in hot water. On standing over night, a small amount of oil was found floating on the surface; this was skimmed off; on pouring off the aqueous solution a heavy oil, small in amount, was found at the bottom. The aqueous solution was transparent, and greenish in color. On evaporating off the water, a thick, dark green, almost black, oily-looking liquid was left behind; this dissolves readily and quickly in cold water. It is entirely soluble in alcohol, but only partly soluble in ether and carbon bisulphide. The alcoholic solution is green, and looks like the aqueous solution. Ether becomes yellow in color, but does not dissolve much; carbon bisulphide acts much like ether. The aqueous solution was extracted with ether until the latter was no longer colored. The aqueous solution was then treated with barium carbonate, to neutralize a small amount of sulphuric acid, and the barium sulphate filtered off. This neutralisation caused the green color to change from green to reddish brown. On evaporation, a mass remains which is black and sticky before complete dryness, but when dry is a brown powder, easily soluble in cold water.

Prof. S. F. Peckham,* in an article entitled "Nitrogen Content of California Bitumen," has shown that the crude petroleums of California contain esters made up of basic oils in combination with an exceedingly viscous, feebly acid, tar. He says when the crude oils are treated with dilute acid, this acid radical forms a hydrate which produces, with the other constituents of the petroleum, an emulsion, from which the aqueous acid solution of the basic oils is sepa-

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* *American Journal of Science, III,* **48,** 250.

rated with much difficulty. In the case of distillates of high specific gravity, the acid radical, or its hydrate, does not dissolve in the oil, so that the acid solution of the bases, the acid hydrate and the oil not acted on by the dilute acid form three distinct layers in the containing vessel. Peckham states that the basic oils belong to the pyridine and quinoline series. He has shown also that by removing these basic oils and the tarry, viscous acid hydrates with which the basic oils were previously combined, the burning and lubricating oils afterwards produced by refining are much superior to those obtained when the above-mentioned bodies are not removed.

If, in the case of the oil volatile with steam, I use dilute sulphuric acid and warm for a time on the water bath, shaking frequently, the dilute acid becomes colored yellowish-red from it; by the addition of sodium hydroxide solution a yellowish-white precipitate is obtained. On standing, a brown oil rises to the surface. It has an odor which reminds me of quinoline rather than pyridine.

From the general similarity between the bodies obtained by Peckham and those resulting from my treatment of oil volatile with steam, I feel no hesitation in expressing the conviction that the bodies obtained from this oil correspond entirely with those obtained by Peckham from the California bitumens. The existence of these basic oils in the California petroleums and in gilsonite is evidence both of their relationship and of their animal origin. Since gilsonite is a hard, brittle solid, and thus removed as far as possible from the petroleum from which it may have been derived by oxidizing agencies, it is a matter of some general interest to note the resemblance in constitution, as shown by these basic compounds. According to the result of analysis of gilsonite, which I have submitted, there appears to be not more than 0·5 per cent. of nitrogen in it, while in the California petroleums the amount exceeds one per cent. In general, the percentage of nitrogen is less in the asphalts than in the petroleums, according to the analytical results thus far obtained. I propose to continue the study of the nitrogen compounds from gilsonite during the present year.

Oil Not Volatile with Water Vapor.—After removal from the water distilling flask this oil appeared thick, black and tarry. It was dried by standing for two weeks over calcium chloride. The first distillation was conducted in a 250 c.c. retort. The boiling began at about 175° C., rising quite rapidly to 230° C., after which the rise was more gradual. The distillate was divided arbitrarily into five fractions. On distilling again the first or most volatile fraction, the boiling began at 175°, rising quite rapidly to 230°, and from that more slowly to 300° C., when only a few drops remained. The distillate was reddish in color, but lighter than it was before the second distillation. There was not much evidence of cracking in this distillation. The remaining fractions are thus evidently liquids boiling at points above 300° C. No solid body separated in the course of any distillation, but the distillates were in all cases liquids of various degrees of consistency.

Action of Nitric Acid.—The highest boiling fraction was subjected to the action of concentrated nitric acid. The weight taken amounted to nearly 100 grams. Violent action took place with abundant evolution of red fumes, accompanied by occasional slight explosions, producing vortex rings in the red vapor and a popping sound. The flask became too hot to touch. After cooling, a quantity of semi-solid oil remained on the surface; the acid was then poured off into cold water. This produced a yellow precipitate of a solid body, which, when collected and pressed into a lump, took a purple color. This, after being pulverized in a mortar, proved to be nearly insoluble in ether, but readily soluble in absolute alcohol; it would not crystallize from this solution. Subjected to the slow action of somewhat diluted nitric acid, the oil, after heating on the water bath for a number of days, gradually becomes thicker, until, finally, it reaches the solid condition, appearing then as a purple solid, having a musk-like odor. It is soluble in ether and alcohol, somewhat more so in the latter. Alkalies slowly dissolve most of it, but some oily-looking matter remains undissolved. The investigation of this material will be continued.

ACTION OF NITRIC ACID UPON GILSONITE.

At first gilsonite was treated with dilute nitric acid, the former in large excess; no definite results were reached in this way. Finally, the nitric acid was employed in concentrated condition and in large excess, when it was found that after about twenty-four hours' continuous heating, during which time brown fumes were continually given off, the gilsonite had entirely dissolved, giving a dark red solution. When this solution is poured into water, a flocculent brown precipitate is produced, looking almost exactly like freshly precipitated ferric hydroxide. This was washed repeatedly with water until all nitric acid had been removed, and then dried on the water bath. Alcohol dissolves most of this substance, leaving undissolved a small quantity of dark-colored material. On evaporation a dark, brittle substance is left. This is soluble in concentrated nitric acid; on pouring into water, a precipitate like the original is produced. Ether dissolves less of the material than alcohol, the greater part being insoluble in ether. The ether solution is yellow in color, and on evaporation leaves a hard, shiny, reddish-yellow varnish-like residue, which may be ground to a fine powder. It dissolves readily in concentrated nitric acid, and on re-precipitating by the addition of water, appears as a light yellow, almost white, precipitate of flocculent character; on heating with water this precipitate melts, shrinks very much, and becomes, on cooling, a hard, brittle substance. It was redissolved in nitric acid and reprecipitated with water a number of times, but no perceptible change in it resulted from this treatment. Alkalies and ammonium hydroxide dissolve it readily; from the solutions thus obtained the substance is re-precipitated, apparently unchanged, by dilute acids. The material thus appears to be an organic acid in apparently quite pure condition. The original precipitate from nitric acid, on being heated in a dry test tube, swells up, giving off a dense white smoke and distilling off a colorless oil, heavier than water. A sort of deflagration takes place, which continues after the removal of the heat. This deflagration appears also with the material dissolved by alcohol, but not at all in the case

of that dissolved by ether. From this it appears that the original brown precipitate produced by pouring the nitric acid solution into water, is a mixture of different substances, one or more of which, as indicated by the deflagrating action, are nitro-compounds easily decomposed by heat, with attendant rapid oxidation. Another ingredient of the mixture is an acid insoluble in water and probably a single chemical compound, which is to be made the subject of further study.

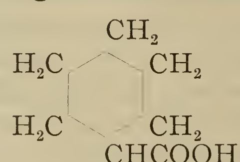
The filtrate obtained on removing the brown precipitate is of a reddish color. This was evaporated upon the water bath, removing the excess of acid and leaving finally a sticky, dark red, gummy mass, soluble in water. As the oxidizing action of the nitric acid in the course of this evaporation appeared to be quite considerable, it was thought best in other cases to neutralize the acid filtrate first with ammonia and then evaporate, thus avoiding further oxidation. The mixture of organic matter and ammonium nitrate thus obtained was first tested as to solubility in ether, but this had very little action in dissolving anything. Absolute alcohol was then tried, with the result of dissolving quite a considerable quantity of organic material, together with some ammonium nitrate. The treatment with alcohol was continued until it came through nearly colorless, being at first dark red. The alcohol was distilled off on the water bath, and the residue, which was liquid when hot, became crystalline on cooling, due, probably, to the separation of ammonium nitrate. It was dissolved in water. On adding lead acetate to this, a light yellow precipitate was formed at once. This was washed, and, on treating with hot water and hydrochloric acid, it was all dissolved. On cooling, lead chloride settled out; this was filtered off, and hydrogen sulphide passed through the filtrate to secure the complete removal of lead. No lead sulphide was, however, obtained. Upon evaporating again, a reddish liquid was left behind, together with some crystals of a substance readily soluble in water and in ether, and giving a strong acid reaction.

The material remaining undissolved by the absolute alcohol above referred to was dissolved in water, lead

acetate was added to this and a heavy greenish-gray precipitate was thrown down. This was filtered and washed with hot water, and then hydrochloric acid was added, which caused the solution of nearly the whole; on filtering this, the solution coming through at first clear, soon separated material looking like the original, and not at all crystalline. The investigation of this material will be continued.

The alkali salts of all the acids obtained are readily soluble, and, on shaking, the solutions give a lather reminding of soap solutions, although they do not appear soapy to the touch. The lead salts are all insoluble in cold water. None of the salts appeared to be crystallisable.

Hell and Medinger* have described an acid occurring in Wallachian petroleum; this, in the conduct and general character of its salts, is quite similar to some of the acids referred to in this paper. The authors just named purified the acid by conversion into the methyl and ethyl esters and fractioning, and afterwards obtaining the pure acid. From the conduct of this acid and its salts, they ascribed to it the formula $C_7H_{12}O_2$, and regarded it as having the structure



or, in other words, a naphthene derivative.

As a result of the present investigation, a method of obtaining from gilsonite a number of acids has been outlined. By further study of those acids and their derivatives, a knowledge of the hydrocarbons present in the mineral may be gained. The distillation experiments have shown that a number of radically different series of hydrocarbons is obtained, and that the paraffin series is one of them, and very probably, also, the naphthene series is another. No aromatic hydrocarbons appear to be present, or, at most, only in small quantity, as in no part of the work

* *Berichte d. deutsch. Chem. Ges.*, **7**, 1216, and **10**, 451.

have derivatives of these bodies suggested themselves. Conclusions drawn from distillation products of a mineral hydrocarbon, as to the constitution of the latter, are necessarily unsafe, on account of the decompositions which take place during the distillation. Much safer conclusions may be drawn from products obtained without distillation from the original material directly by the action of reagents such as nitric and sulphuric acids.

Markownikoff,* who isolated aromatic hydrocarbons in petroleum from Baku, condemns the use of bromine or nitric acid to detect aromatic hydrocarbons, since, he says, these reagents are liable to give aromatic derivatives from the naphthenes. He prefers, on this account, to use sulphuric acid, obtaining the sulphonic acid, and from this to pass to the hydrocarbon by distilling with lime from an iron retort. The action of concentrated sulphuric acid upon gilsonite is now under investigation by the writer, but, as yet, without definite or even promising results.

In conclusion, I may express the hope that in a future paper I may be able to give definite conclusions resulting from the study of the acids referred to in this communication, and also results of further study of basic oils. I am indebted to Prof. S. P. Sadtler for aid in my review of the literature, and to Miss A. T. Coons and Mr. A. H. Scott, of Swarthmore College, for valuable aid in the laboratory.

SWARTHMORE COLLEGE, PA., June 18, 1895.

NOTES AND COMMENTS.†

TELEGRAPHING WITHOUT WIRES.

Prof. A. E. Dolbear, in the *Electrical Engineer*, says: The increasing interest in the attempts to telegraph without wires both here and abroad makes it worth while to make mention of some facts which have been forgotten or ignored, and I venture to point out that the method which has lately been employed so successfully in England for telegraphing across a sheet of water between three and four miles wide with no connecting cable was fully described by Prof. John Trowbridge, of Harvard University, in

* *Annalen d. Ch. u. Pharm.*, **234,** 89.

† From the Secretary's monthly reports.

1880. He made his original researches between the Observatory in Cambridge and the city of Boston, between which is a time signal wire having the circuit broken by clock once a second. He found he could hear the clock-beats a mile away from the line by connecting a telephone to a wire 500 or 600 feet long and grounding their ends parallel with the circuit.

His experiments and conclusions are detailed in a paper given before the American Academy of Arts and Sciences, and are published in its *Proceedings* for 1880. How completely he covered this ground of doing telegraphic work by means of earth conduction will be seen by the following quotations from those *Proceedings* :

"The theoretical possibility of telegraphing across large bodies of water is evident from this survey which I have undertaken.

"Theoretically, however, it is possible to telegraph across the Atlantic Ocean without a cable. Powerful dynamo-electric machines could be placed at some point in Nova Scotia, having one end of their circuit grounded near them and the other end grounded in Florida, the conducting wire consisting of a wire of great conductivity and being carefully insulated from the earth, except at the two grounds. By exploring the coast of France, two points on two surfaces not at the same potential could be found, and by means of a telephone of low resistance the Morse signals sent from Nova Scotia to Florida would be heard in France."

This is precisely what is being done in England, carrying out Trowbridge's method. In the various descriptions of methods and operations which I have seen there is no mention of the work of Trowbridge, and whatever merit and utility there may be in this method of doing telegraph work belongs to him. Shortly after the publication of the paper from which I have quoted, Dr. Edward Everett Hale wrote a short story for the *Atlantic Monthly*, in which these earth sheet currents played an important part. Beyond that, I have never seen mention of the discovery, for it was a discovery, and an important one too, that slight currents could be detected at relatively great distances from their source by means of a telephone connected to the ground.

THE CHICAGO CANAL AND LAKE COMMERCE.

Those interested directly in the commerce of the great lakes are manifesting much interest, and more or less apprehension, in regard to the reduction in water level that will follow the completion of the Chicago drainage canal, and the effect on the lake carrying trade. Careful calculations have been made to show the fall that will result when the canal is flowing at its maximum and minimum rates, and estimates have also been made of the decrease in capacity of the lake fleet due to a permanent reduction of the water level. From a report made by Thomas T. Johnston, assistant chief engineer in charge of the hydraulic work of the canal, we find that the level of Lake Michigan will be lowered between five and six inches when the canal is taking the maximum quantity, 600,000 cubic feet per minute. At the

minimum flow of the canal, 300,000 cubic feet per minute, the reduction will be only a little over one inch. The former estimate is made when Lake Michigan is at its highest normal level. It is thought that the average reduction for the average flow through the canal will be between three and four inches.

Regarding the effect on lake traffic of a reduction in level, we find considerable data in a report prepared by C. H. Keep, Secretary of the Lake Carriers' Association, at the request of Major E. H. Ruffner, Corps of Engineers, U. S. Army. This report is an estimate of the decrease in capacity of the lake fleet caused by a fall of three, six or nine inches in the mean level of the lakes. The list of vessels on the great lakes engaged in the carrying trade and of sufficient importance to be classed for insurance, was obtained from the *Inland Lloyd's Register.* It was assumed that all the vessels not classed were too small to have their carrying capacity affected by a lowering of the levels within the limits set for the investigation. Vessels known to be of light draft and those under 250 tons net register were not considered. The estimate is, therefore, restricted to vessels carrying package freight, grain, coal, ore and lumber. These vessels were arranged in eleven different classes or groups, according to size and carrying capacity, and types of each class were selected to show what cargoes are carried at different drafts. From these data estimates would show how much the carrying capacity of the entire fleet would be diminished in the case of a single load for each vessel; but to find the decreased capacity for a season, it became necessary to estimate the number of full loads carried during the season. This was estimated as being twenty-five loads per season for steamers and fifteen loads for schooners, which would represent a total of 33,000,000 tons of freight carried in a season. Upon this basis the following results are obtained:

A lowering of the lake levels by three inches would produce a diminution of the carrying capacity of the lake fleet in a season amounting to 1,142,370 tons; a lowering of the lake levels by six inches would diminish the carrying capacity 2,284,740 tons; and a lowering of the lake levels amounting to nine inches would diminish the carrying capacity 3,427,110 tons. Turning these results into dollars and cents, and estimating the earnings of lake vessels at an average of 50 cents per ton of cargo carried, over and above cost of loading and unloading, a lowering of three inches would diminish the earnings of the fleet in a single year $571,185; a lowering of six inches would diminish the earnings $1,142,370, and a lowering of nine inches would diminish the earnings $1,713,555.

It is evident, particularly to those familiar with the wide fluctuations in the levels of the great lakes, due to natural causes, a dry or a wet season, that the accuracy of calculations of this character, no matter how carefully prepared, may be questioned. The initial factors in the problem are too uncertain to permit of unimpeachable conclusions being drawn. While the calculations are of great interest, their value, as outlining the probable effect of the completion of the canal upon lake commerce, may be doubted.—*The Iron Age.*

THE "DEADLY" TROLLEY CAR FENDER.

Referring to the notorious inefficiency of the fenders at present in enforced use upon the surface electric roads in many of our cities, the *Electrical Engineer* strongly reiterates its belief, long before expressed, that "good brakes are more necessary to the cars than poor fenders; and we hope ere long to see public opinion intelligently directed to that part of the subject. But, with the best of brakes, suicide will remain possible to those who seek to kill themselves on the trolley lines. As one of the Philadelphia papers says, the city itself owes some duties to the citizens other than putting petticoats around the cars, and the necessity of rapid transit must not be subordinated to the unchecked carelessness of stupid foot-passengers. In other words, it approves the Berlin rule that arrests the man who is run over. Speaking of the children, it says, very sensibly: 'There is but one power that can keep children from the streets, and that is the power of the police. There is not a day that scores of children cannot be seen playing on the streets occupied by trolley lines, in every part of the city, and until they are forbidden by the police, and arrested when they disobey the order of the city authorities, there will be no safety for children, fenders or no fenders. Children must be protected by a stronger power than themselves, and the only power that can protect them in a great city is the power of the municipality.'

"The above quotation is a cheering sign that the discussion of trolley car accidents is at the stage when the truth is about to prevail."

SUCCESSFUL TRIALS OF THE ELECTRIC LOCOMOTIVE.

The recent trials of electric locomotives at Nantasket Beach, near Boston, and at Baltimore, have so satisfactorily demonstrated the superiority of this class of motor over the steam locomotive for short hauls, that it is now very generally admitted that the near future will witness a very extensive application of the new form of motive power for short branch lines, tunnel haulage, elevated roads in cities, and the like.

At the Nantasket Beach trials it is stated that a speed exceeding sixty miles an hour was attained; and the experiment demonstrated the utility of this motor for suburban traffic. The system went into practical and regular operation on the Nantasket Beach Railway at the end of June. The test made at Baltimore of the electric locomotive designed to draw trains through the tunnel, 7,430 feet long, in that city, was also highly successful. This and its companion—the first locomotives of the kind ever built—have each two trucks and eight wheels, sixty-two inches in diameter. Flexibly supported on each truck are two six-pole gearless motors, one for every axle. A maximum speed of fifty miles an hour is to be developed, and it is guaranteed that the locomotive will pull 1,200 tons at a speed of thirty miles an hour. When coupled to a six-wheel New York Central locomotive, the electric locomotive pulled it up and down the track at will, against the pull of the steam locomotive.

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IRRIGATION; WITH AN EXAMPLE OF ITS APPLICATION IN THE ARID REGION OF WESTERN AMERICA.

BY A. B. WYCKOFF.

I. IRRIGATION.

Irrigation antedates authentic history. This statement is proven by the existence of most wonderful ruins in Asia and Africa, of pools or reservoirs, canals and aqueducts, of the construction and use of which only the most indefinite and unsatisfactory traditions can be obtained. Surmises exist in abundance, but no actual knowledge. These great monuments of hydraulic engineering have excited the wonder and admiration of modern scientists. In fact, until within a generation of the present, no practical advance had been made in the science of irrigation for 3,000 years. Many of the great irrigation works of antiquity were destroyed or abandoned as the results of wars or the convulsions of Nature, and as the ancient local civilization disap-

peared, the lands again became desert, and the small remnants of the races sank into savagery and barbarism.

The extent of some of these great hydraulic works can be conjectured from the ruins remaining. Lake Maeris, in Egypt, was constructed at least 2,000 years before Christ. Its dimensions were sufficient to regulate the annual inundation of the Nile, receiving the surplus waters when there was danger of a flood, and supplying the needed deficiency when the river reached a stage which would not irrigate the crops. This, with other large reservoirs of flood waters, enabled a population of 20,000,000, to exist in the valley of the Nile, while it now supports barely one-fourth of the number.

In ancient times the valleys of the Euphrates and Tigris, now almost a desert, were densely populated. Four thousand years ago the rulers of Assyria had converted those sterile plains and valleys into gardens of extreme productiveness, by the construction of immense artificial lakes for the conservation of the flood waters of the rivers, and great distributing canals for irrigation. One of these canals, supplied by the Tigris, was over 400 miles long and from 200 to 400 feet broad, with sufficient depth for the navigation of the vessels of that time. Throughout Judea the ancient Jews constructed many pools, tanks and wells for the irrigation of their fields. The Greeks of that age also understood the science of hydraulics, as is shown by the remains of great aqueducts. The Phœnicians converted a portion of Northern Africa into fields and gardens by extensive irrigation works. The Romans thoroughly mastered this science and drained the Pontine marshes, supplied Rome with the purest water and developed the agricultural resources of Italy. In France, Spain and Portugal they built aqueducts to supply the cities with water, and canals to irrigate the valleys. In India, tanks, reservoirs and irrigating canals were constructed many centuries before the Christian era, and a great part of that country was kept in the highest state of cultivation. Some of the tanks or artificial lakes covered many square miles, and were often fifty feet in depth. The English Government, in recent years, has re-

opened the ancient irrigating canals, and has built thousands of miles of new ones to prevent the recurrence of the dreadful famines formerly experienced in that densely populated country. About $200,000,000 have been expended on these works, which pay a good interest on the investment through water rentals and the enormously increased revenue from the land taxes. In addition to the millions of acres reclaimed by the government works, each village has its tank, built of masonry and concrete, for domestic and irrigation purposes. The English also found extensive irrigation works in Ceylon, which they have improved and amplified during the last thirty years, thereby greatly increasing the population and revenues.

Most of the canals of China probably antedate the Christian era. They intersect the country in every direction and are used for navigation as well as irrigation. The water is lifted from the canals by primitive pumps or wheels worked by men or oxen. There is no extensive storage of water, although the country is well suited for it. While there are no ancient works in Japan, the entire arable lands, even to the tops of the hills, are most highly cultivated by small community irrigation systems, which conserve all the water from the numerous springs and streams.

America is not without ancient irrigation systems, as is proven by the ruins of extensive canals and large reservoirs found in Peru, Bolivia, Chili and the Argentine. Some of these have been renewed and new works constructed, especially in the Argentine Republic. Evidences exist in New Mexico and Arizona that in prehistoric times, a race now extinct, had extensive irrigation works and cultivated large areas. Some of the Indians in New Mexico, and the Moqui, Maricopa and Pima tribes in Arizona, have lived upon the same lands for hundreds of years by means of primitive systems of irrigation.

The importance of this subject is shown by the fact that more than half the human race subsist upon the products of irrigated lands. To a resident of the humid regions this statement is no doubt startling, but even a cursory investigation will convince him of its truth. The rice-eaters out-

number the wheat-eaters more than two to one, and all rice is grown by irrigation. The hundreds of millions in China, Japan and India live almost entirely on rice.

It is only recently that irrigation has become an important factor in our political economy. As long as the surplus population of the older States could obtain homes on the public domain in the humid regions, no thought of the reclamation of the arid lands was entertained. The insatiable craving for 160-acre farms even led to the settlement of the semi-arid regions of western Kansas and Nebraska, where the rainfall was known to be insufficient and unreliable. The result has been years of suffering and lost efforts, and even appeals to older communities for food. Had the past history of the world been rightly studied by our political economists, these hardy and intelligent pioneers might have been directed to the arid valleys of the great West, where prosperous and independent communities would now exist. But the practice of our farmers has been anything but practical and economical, and intensified cultivation and diversified crops are still repugnant ideas to the great majority of our agriculturists. However, the time has arrived when the problem of our arid lands has become one of the most important before our legislators. The tide which has so long been setting towards the cities must be turned to suburban life if we are to escape social convulsions. There are thousands of intelligent and industrious men anxious for country homes, but without knowledge as to where they can be found. They are told that Uncle Sam's free land is exhausted and, in consequence, when an Indian reservation with poor soil in some semi-arid region, is thrown open to settlement, there are thirty men on the rush line for every homestead. The money spent in reaching the reservation and waiting for the opening would have enabled them to acquire small prosperous homes under some irrigating ditch.

The country must be educated before the congested East will be relieved of its surplus population, and the arid lands of the West be settled. No more important practical and social question confronts us, and the philanthropists, states-

men and editors, should embark in this great educational movement. Already eminent men in Boston and Chicago have begun the formation of societies, similar to Chautauqua circles, to disseminate information regarding this subject, and they should be started in every town and village in the land. It is, no doubt, difficult to interest the residents of the humid regions in this matter; but after their experiences during the past few months, descriptions of the constant genial weather and abundant crops of all kinds in irrigated districts of the West should arouse a veritable enthusiasm and lead to a new crusade in search of homes in the arid regions.

With irrigation, agriculture is made a safe and secure investment. Contrast the life of a farmer under a good irrigation canal with one in the humid regions: the ever-corroding anxiety of the latter, watching and praying for rain while his crops wilt and die, or the sudden blasting of his hopes by storm and flood; while the former, in perfect security, cultivates his crops and turns in the life-giving waters when necessary. Compare, again, the existence of a clerk or mechanic, no matter how good his position, with the owner of twenty acres of unmortgaged irrigated land, cultivated to insure an abundance of nearly everything that his family consumes. The one is a servant with an insecure living, while the other is a virtual sovereign in his security and independence. In no situation in life should there be as much health, happiness, freedom and contentment for the average family as on the little irrigated estate, for their modest wants can be met and their daily bread secured as long as they remain frugal and industrious. The experience of a ministerial friend illustrates so aptly the difference that I may be pardoned for introducing it here. He was making a long bicycle trip, and at midday arrived at the residence of a farmer in western Kansas. He saw in the fields about the house very thriving and abundant crops, in great contrast with the locality through which he had recently passed. Although not in clerical garb, the good man thought that he should put in a word in season, and at the close of the meal, to which he had been invited,

he remarked to his host: "Mr. Brown, I noticed that you have very thrifty and abundant crops. You should be very thankful to divine Providence." The farmer looked at him for a moment and then said: "Stranger, we don't care nothing for Providence here, we're under the company's ditch."

As irrigation is the artificial application of water to land for the purpose of promoting agriculture, it follows, on account of the limited water supply, that only a small proportion of our arid lands can ever be brought under cultivation. But that does not proportionately diminish its economic value in comparison with the much greater area of the humid regions, for, as acre to acre, they are as six or eight to one. In other words, an industrious family on a twenty-acre farm, under an irrigating ditch, will attain a more secure and permanent prosperity than on the usual quarter section of land in the humid regions. In addition to the security of an independent livelihood, the arid regions offer other advantages. The larger amount of sunshine and dryness of the atmosphere conduce to greater healthfulness and more optimistic views of life. The small farm means intensive cultivation and more intelligence, nearer neighbors, less loneliness, greater social advantages, more churches, schools, telephones, electric lights, good roads—in fact, a new civilization with better homes and greater enjoyments than have been known in the older agricultural regions. The resultant man and woman should be a nobler type, with freer, fuller lives than the nervous, careworn, typical American.

Where are these new homes to be found, and how can they be secured? The one-hundredth meridian is virtually the boundary line between the old and the new. The older subjugating conquest of the continent stopped there, except in the localities settled by mineral developments and the narrow humid region along the Pacific Coast. This vast empire was once considered worthless by our statesmen, except for its mineral wealth and as a range for cattle and sheep. And yet this empire offers greater and more prosperous industrial possibilities than any other portion of our

country, because its resources are more varied and extensive. The land of the sage brush and jack rabbit is the most fertile and productive in the world, wherever water can be brought upon it, for nowhere is the soil so rich and the sunshine so constant.

In the arid and sub-humid regions the Government still owns 570,000,000 acres. About 20,000,000 acres are in parks and 60,000,000 acres in Indian reservations. There are other lands given to States and private enterprises, but not yet patented, which would reduce the lands open to settlement to about 450,000,000 acres. Of course, the lands given States and corporations can be purchased, and much of the area of the Indian reservations will eventually be thrown open for settlement. A large percentage of this region is mountainous and not arable, and a still larger portion must remain desert and grazing lands from the absence of any known water supply for its reclamation. The most careful estimates of the reclaimable lands, without increasing their cost beyond a profitable figure by expensive reservoirs and canals, is 50,000,000 acres. Other sources of phreatic and artesian supply may be discovered, but it is not probable that more than 60,000,000 acres can ever be brought under cultivation by irrigation. However, that means a new empire, as, under the economic conditions of irrigated farming, that amount of land will support an urban and suburban population of at least 30,000,000 people.

These lands may be assigned to the different States about as follows:

Arizona	2,000,000
California	10,000,000
Colorado	5,000,000
Dakota	1,000,000
Idaho	4,000,000
Kansas	1,000,000
Montana	8,000,000
Nebraska	1,000,000
Nevada	2,000,000
New Mexico	3,000,000
Oregon	2,000,000
Utah	3,000,000
Washington	2,000,000
Wyoming	6,000,000

One result of the reclamation and utilisation of large areas of the arid lands through irrigation will probably be the increase of the rainfall in the sub-humid regions adjoining, to an extent which will render them far more valuable and reliable for the cultivation of the cereal crops. Most of the above acreage is already in private ownership, but as ditch companies hold large areas obtained through the desert law, or purchased from railroad companies, it can be bought at reasonable prices, on long-time payments.

A conservative estimate of the amount of land under ditch is about 25,000,000 acres, and probably one-half of that is under cultivation. Statistics gathered by the Government experts in the last census make the average expense of reclamation $8.15 per acre. The first ditches were built close along streams where the land was comparatively level, and the cost was merely nominal, but in some of the later projects, embracing immense reservoirs and concrete aqueducts, the expense has been $100 per acre. The reclaimable lands not yet under ditch will necessitate much more difficult engineering, and will raise the average price per acre of reclamation very considerably. The average annual return from irrigated lands, according to the census, is $14.87 per acre. This is much lower than it should be, as grass and pasturage lands are included in the estimate. Even that figure is, however, at least three times the average return of all the farms in the country cultivated without irrigation. The value of irrigated lands will soon become so great that in the near future the large ranches now devoted to pasturage and cereal crops will be divided into small holdings, when intensified farming will more than double the annual productiveness, and the estimated average value of $83 per acre.

Riverside, Cal., may be taken as an example of what irrigation will accomplish. The land, in 1870, was rated at $1 per acre. About $100 per acre was expended in bringing water to the lands. It is estimated that the annual return from the citrus orchards is from $200 to $300 per acre, and they have frequently sold as high as $1,000 per acre. Near Fresno, Cal., unimproved sage brush land, under ditch with

SAGE BRUSH LANDS IN ARID REGION.

THE YAKIMA RIVER, WASH.

water right, sells from $100 to $300 per acre. Before the day of irrigation it could be bought for $2 per acre. These results are, of course, far above the average, but there are few localities in the arid regions where the crops from irrigated lands, with intensified farming, will not justify an average price of $100 per acre. When it is less, it is due to unusually poor soil, distance from market, or a poor water right. This estimate is made in comparison with the price of improved farms in Illinois or Iowa, and their average annual productiveness. Lands under ditch can now be bought in many localities for less than half that price, and on easy terms; but as the arid regions become settled, the average yield of irrigated lands, even in varied crops, will justify the larger price per acre.

YAKIMA COUNTY, WASHINGTON.

This county lies between latitudes 46° N. and 47° N., and longitudes, 119° W. and 122° W. It contains 5,580 square miles, or 3,571,200 acres, and is somewhat larger than the State of Connecticut. The Columbia River, one of the largest in the United States, borders the county on the north and east for over eighty miles, while the summit of the Cascade Mountains forms its western boundary. The Yakima River has its source in several lakes near the crest of the Cascades, and flows diagonally through the county from northwest to southeast, cutting through several basaltic ridges and the enclosed basins. A number of streams flow into the Yakima, principally from the westward. One of these, the Natchez River, is fed by the glaciers of Mount Ranier, and is almost as large as the Yakima itself above the junction. As is well known, the Cascade Mountains, trending north and south, divide the State of Washington into two nearly equal parts. On the west there is an excessively humid region, with the densest forests of enormous trees reaching from the snow-line down to Puget Sound and the Pacific Ocean. On the east, the descent, at first, is very abrupt, but branching ranges and the foot-hills extend long distances, enclosing valleys, which are heavily wooded at the higher elevations, and merge into sage brush and aridity

at their lower ends. Large streams flow through each of these valleys, furnishing the means for their reclamation.

The Cascade Mountains are composed largely of volcanic rocks. They vary in height from 5,000 to 15,000 feet, the latter for Mount Ranier, probably the highest peak in the United States, except Mount St. Elias, in Alaska. This mountain is situated on the western border of Yakima County, while Mount Adams, nearly 10,000 feet high, is wholly within it. Both are extinct volcanoes, although the volcanic heat is still escaping through fissures in their craters. A number of spurs from the Cascades, from a few hundred to 3,000 feet high, run off to the eastward, gradually diminishing in height as they approach the Columbia River. These usually have a gentle slope on one side, conforming to the dip of the strata of which they are composed, but a bold scarp on the other. It is a question with geologists whether these basaltic ridges have been caused by the cooling of lava streams flowing from the volcanoes, or are the results of fractures of the horizontal strata and uplifts radiating from the mountain range. Their peculiar formation, with gentle slope and abrupt scarp, would appear to confirm the latter theory.

Prof. I. C. Russell, of the Geological Survey, after an examination of this region, concluded that underlying the county was a great series of lava sheets, composed principally of basaltic rocks. As the region of this lava flow is drained by the Columbia River, he named it "Columbia Lava." It occupies an area approximately of 200,000 square miles, and varies in thickness from a few hundred to several thousand feet. The Columbia Lava is not one vast flow, but is composed of many separate flows, sometimes separated by land surfaces which contain the stumps of large trees. This extensive series of volcanic overflows ended in a lacustral period when the whole of eastern Washington and Oregon was one vast lake. Many streams washed mud and sand into it, and active volcanoes strewed it with ashes. This accumulation of sediment went on for ages until it was several hundred feet deep. As these lake accumulations were first examined and described

along the John Day River, in Oregon, they were named the "John Day" system. These lake deposits are unconsolidated sediment, sometimes sufficiently compact to make soft sandstone. The layers of sediment are interbedded with light flows of lava, especially on the lower levels. The great disturbances which pushed up the basaltic ranges and hills have occurred since the deposit of the John Day beds. During the existence of Lake John Day, the climate was variable, but mild, and there was a beautiful flora. After it came the glacial age. The great glaciers of the Cascades and regions farther north did not reach Yakima County, but the melting ice formed a lake, which covered a large part of central Washington. This lake, from the small amount of sediment deposited in it and the not clearly marked beach lines caused by its waves, was probably of brief existence. That it covered the lower valleys in Yakima County is certain, as many granite and basaltic boulders are found which must have been brought from much farther north and dropped by melting icebergs floating in the lake.

The last geological episode that occurred in Yakima County was a lava flow of molten rock from the headwaters of the Tiaton Creek, a tributary of the Natchez River. It flowed in an easterly and southeasterly course for some forty miles, ending at the junction of the Natchez and Cowychee Rivers. It was from 200 to 500 feet thick and from one to two miles wide. This flow of molten rock must have occurred after the deposition of the John Day beds and the subsequent upturning of the horizontal strata. Weathering and erosion had cut away the soft lake deposit into drainage lines, one of which this latest overflow followed, forcing farther apart the Natchez and Cowychee Rivers. Unlike the older volcanic deposits, this youngest lava is not a basalt, but a good example of hypersthene andesite.

A topographical description of Yakima County is extremely difficult, because of the great convulsions of Nature which have broken the surface in all directions, and the subsequent weather erosions continuing through many centur-

ies and forming numerous drainage basins. In the extreme eastern part of the county is a triangular plain, about fifty miles long and twenty miles broad at the north. Its elevation in the eastern part is slight, but the plain gradually rises to the westward until it terminates at the Rattlesnake fault, which reaches a height of 2,000 feet above the Columbia River. To the southward of the Yakima River, in the southeastern part of the county, is an elevated plateau sloping away from the high hills to the northwest down to the Columbia River. This plateau is called "Horseheaven," from the abundance of bunch grass, and, being in the Columbia River basin, is much more humid than the remainder of Yakima County. Neither the Rattlesnake nor Horseheaven plains are favorable to the finding of a supply of artesian water, as the strata slope away from great faults on the westward, and are not again upraised to form a catchment basin. From the elevation and situation of the Horseheaven country it will be impossible ever to reclaim it by gravity irrigation, except through the construction of reservoirs to conserve the rainfall. In the western part of the county is a mountainous region, where the numerous streams have their sources. It comprises about 1,000,000 acres, and is covered with a heavy growth of pine, spruce and fir. The remainder of the county contains the irrigable lands, which are found in the Yakima and tributary valleys. As before stated, the Yakima River runs diagonally through the county for 125 miles, and has various tributaries from the westward, each watering considerable valleys. Beginning at the northern end of the county, these are as follows, viz.: Wenas, Natches, Cowiche, Ahtanum, Toppenish and Satus. On the east side of the Yakima lie the large Moxee and Sunnyside valleys, which are without streams, but can be largely watered from the main river.

Geologists have maintained that no artesian basin existed in Yakima County, on account of the very broken condition of the country, caused by frequent volcanic action and upheavals of the earth's crust destroying all regular stratification. Lying in the central part of the county, and east of the river, is the dry Moxee Valley, some twenty-five miles

long and averaging five miles in width. This valley owes its existence to the upheaval of its borders, and has a rapid incline towards the Yakima River. Several thousand acres of fine land in the eastern portion of the valley could not be redeemed by gravity irrigation. In consequence, notwithstanding the unfavorable prognostications, a well was started in 1891, about eight miles from the river, and 200 feet above it. A strong flow of water was struck at a depth of 314 feet, which rose in an open tube twenty-six feet above the surface. Seven flowing wells have since been put down at surface elevations, varying from 1,085 to 1,166 feet above sea level. The most easterly wells found good flows of water at from 300 to 500 feet, while those nearer the river had to go twice as deep. The temperature of the water varies from 65° F. in the shallowest well to 75° F. in the deepest. The dip of the water-bearing strata seems to be about 200 feet to the mile. All of the wells show sections having somewhat similar characteristics, but varying as to depth and material of the different strata. They are throughout John Day beds (gravel, sand, clay, shale, sandstone), interstratified with thin sheets of Columbia lava, except in the extreme easterly wells, which encountered no basalt. It is probable that the records of the borings were not kept with sufficient care to make them thoroughly reliable, but enough data were obtained to show that the stratification is very much broken.

A clear elucidation of the question of the source of this artesian supply, under the circumstances, is quite impossible. The difference in the depth of the several wells, and of the temperature of the water, indicate different sources of supply, but the fact that no flowing water can be obtained at a greater surface elevation than 1,190 feet above the sea, as shown by three unsuccessful attempts, leads to the conclusion that the sources are virtually the same, only affected by peculiar local conditions in each instance. The strata are turned up on edge at the sides of the valley, but the limited rainfall precludes the idea that there is a reservoir supplied by the small catchment on the adjacent ridges, especially as the flow of the wells has continued regular throughout several years. The high temperature and the constant plane

above which the water will not rise, would seem to indicate that the artesian basin is an accidental one, fed through fissures in the Columbia lava. The high temperature of the water may be caused by its deep source, or by the lava through which it passes not having cooled down below the temperature shown. A well drilled about eighteen miles west of the Moxee group, and the same distance from the river on the opposite side, at an elevation of 1,125 feet, went down 630 feet through the John Day beds without encountering any basalt. Water was reached at eighty feet from the surface, but apparently under no pressure. The erosion of the deposits in the Moxee has evidently been much greater than in the Ahtanum Valley. A well sunk 630 feet in the Horseheaven country, in the southeastern part of the county, struck a thick stratum of basalt at a depth of twenty feet, showing that the surface had been almost entirely denuded of the John Day beds.

The total area of irrigable lands in the county, which can be reclaimed at reasonable cost, amounts to about 650,000 acres. As the Yakima River and all its tributaries have very rapid falls, and are not sunk in deep channels, the construction of irrigating canals is a matter of comparatively small expense. The streams being fed by the springs, snows and glaciers of the Cascade Mountains, the Yakima Valley enjoys the unique advantage of being the only locality in the country which has an ample and unfailing supply of water throughout the crop season. In fact, the superabundance of water has thus far been rather a drawback upon the obtaining of the best results, from the tendency of the farmers, nearly all of whom are unacquainted with proper irrigation methods, to flood their crops with too much moisture. It can be appreciated what this means when it is stated that if every drop of running water were utilised in Nevada and Arizona during the season, there would not be sufficient to irrigate one-half of one per cent. of the arid lands in those States.

The following report, made by the United States Geological Survey, shows the average discharge of the Yakima River, taken near its mouth. During the irrigation season,

from March to November, these amounts should be increased by the water already utilised in existing ditches:

	Cubic Feet per Second.
January	4,030
February	5,111
March	10,786
April	11,460
May	21,500
June	17,930
July	5,090
August	2,480
September	2,248
October	2,662
November	4,874
December	4,412

The following is from the report of Engineer F. H. Newell, of the Geological Survey:

"Comparing the estimated October discharge of the Yakima River with that of other rivers, the remarkably large volume from a relatively small watershed is apparent. This is best shown by the following table, which gives the discharge of various streams for October, 1893, and also in several cases for the same month in preceding years. Opposite to this, for comparison, is placed the area drained, and in the third column the area drained by square miles of catchment. These last figures bring out most strongly the large flow of the stream. All quantities of water are given in second-feet (cubic feet per second of time), equaling about fifty miner's inches, as commonly measured:

	Discharge, Second-Feet.	*Drainage Area, Square Miles.*	*Run-off per Square Mile, Second-Feet.*
Yakima, 1893	2,692	3,300	0·81
W. Gallatin, 1893	576	850	0·68
Yellowstone, 1893	1,630	2,700	0·60
Missouri, 1891	3,511	17,615	0·20
Arkansas, 1890	505	3,060	0·17
Arkansas, 1891	624	3,060	0·20
Arkansas, 1892	511	3,060	0·17
Rio Grande, 1892	259	1,400	0·18
Rio Grande, 1893	263	1,400	0·19
Bear, 1891	980	4,500	0·22
Bear, 1892	780	4,500	0·17
Bear, 1893	737	4,500	0·16

"From the inspection of this table, which might be extended to a far greater length, it is apparent that the canal owners taking water from this stream have far less to fear as regards their water supply than have irrigators in other parts of the arid regions."

The following table is taken from the United States Geological Survey of 1891-92. Since that time the irrigated

States and Territories Employing Irrigation.	Crop Irrigated. Acres.	Per Cent. of Area of Irrigated Crops to Total Land Area.	Total Number of Farms with Irrigated Crops.	Average Size of Irrigated Crops per Farm. Acres.	Average First Cost of Water per Acre.	Average Value of Water per Acre as Estimated by Irrigators.	Average Annual Cost of Water per Acre.	Average Cost of Preparing Land for Cultivation per Acre.	Average Value of Land Irrigated per Acre.	Average Value of Products from Irrigated Land per Acre.
Arizona	65,821	0·09	1,075	61	$7 07	$12 58	$1 55	$8 60	$48 68	$13 92
California	—	1·01	13,732	73	15 84	52 28	1 60	22 27	150 00	19 00
Colorado	—	1·34	9,659	92	7 15	28 46	0 79	9 72	67 02	13 12
Idaho	218,249	0·40	4,333	53	4 74	13 18	0 80	9 31	46 50	12 93
Montana	350,582	0·38	3,706	95	4 63	15 04	0 95	8 29	49 50	12 96
Nevada	224,403	0·32	1,167	192	7 58	24 60	0 84	10 57	41 00	12 92
New Mexico	91,745	0·11	3,085	30	5 58	18 30	1 54	11 71	50 98	12 80
Oregon	177,944	0·29	3,150	56	4 64	15 48	0 94	12 59	57 00	13 90
Utah	263,473	0·50	9,724	27	10 55	26 84	0 91	14 85	84 25	18 03
Washington	49,399	0·12	1,050	47	4 03	13 15	0 75	*10 27	50 00	17 09
Total United States	3,564,416	0·50	52,584	67	$8 15	$26 00	$0 99	$12 12	$83 28	$14 89

* NOTE.—This cost of $10.27 has been calculated by including cost of leveling land for irrigation. This is very fluctuating. The cost of clearing the sage brush and repairing fairly level land may be taken at $4 per acre.

YAKIMA INVESTMENT COMPANY'S CANAL, SUNNYSIDE VALLEY, WASH.

REVERSED SIPHON OF YAKIMA VALLEY CANAL COMPANY, COWICHE VALLEY, WASH.

VINEYARD AND ORCHARD, YAKIMA VALLEY, WASH.

VIEW NEAR NORTH YAKIMA, WASH.

crop of Washington has probably doubled, and most of the increase has been in this county. This table proves that the first cost of securing water and the annual expense of maintaining the ditches is less than in any other State, while the percentage of value of crops, as compared with value of land, is much greater.

The Yakima Indian Reservation, containing 887,000 acres, is in the central part of the county, and extends from the Yakima River westward to the summit of the Cascade Mountains. The lands lying along the river are level, rising gently to the westward, and over 100,000 acres can readily be brought under irrigation at moderate expense. Allotments in severalty have been made to the Indians, and it is probable that the remainder of the reservation will soon be thrown open to settlement. As the Indians, about 1,900 in number, are far advanced in civilization and are self-supporting, they are not objectionable neighbors, but, on the contrary, are the most valuable hands that can be employed in the hop fields.

The climate of Yakima County is exceptionally good. The prevailing westerly winds lose their excessive moisture on the crest of the Cascades, so that there are no fogs, but few cloudy days and only about ten inches of annual rainfall. The frost leaves the ground in February, and farming can be begun by the end of that month. The winters are mild and short, with an absence of wind, and almost constant sunshine. The springs are cool, and while there is considerable wind it is purely local, and, on account of the sheltering mountains, never attains any destructive velocity. The summers are long and warm, but with cool nights, while the autumns are very pleasant. During the past six months, while the remainder of the United States has been suffering such extreme vicissitudes of climate, this valley has enjoyed constant delightful weather. The following tables are the reports of the United States weather observers, and are taken at widely separated stations in the county:

MEAN TEMPERATURE.

Location.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June.*	*July.*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
North Yakima	27	29	43	49	58	65	72	72	59	49	40	30
Fort Simcoe	31	32	42	52	62	66	72	74	64	52	42	33
Kennewick	33	34	51	55	64	70	78	77	64	52	42	33

RAINFALL.

North Yakima	0·85	1·42	1·04	0·96	1·48	0·45	0·25	0·01	0·14	0·58	0·94	1·52
Fort Simcoe	2·14	2·17	1·34	0·74	0·98	0·32	0·19	0·04	0·24	0·81	1·20	2·23
Kennewick	1·58	0·42	0·30	0·39	0·49	0·38	0·02	0·01	0·22	0·54	0·63	1·28

The prevailing hygienic conditions are admirable. There are no sudden changes or cold, piercing winds, and while the summers are long and warm, there are no sultry days, and the cool nights permit refreshing sleep. Farmers can work in the fields the hottest days, and sunstrokes are unknown. The altitude and dryness of the atmosphere prevent the enervating effects of the hot, moist days of humid localities. Local physicians assure me that the climate is beneficial in all asthmatic, pulmonary, bronchitic, neuralgic and rheumatic affections.

The soil consists mostly of sedimentary materials deposited at the bottoms of the lakes, which covered these valleys for centuries, and was at one time of great depth. Weather erosions have removed much of it, but in the valleys it still remains very deep. It is largely disintegrated basaltic rocks, and contains all the chemical elements necessary for great productiveness. While it is porous and absorbs water, yet it has good consistency, is easily worked and does not bake like clayey lands. In Arizona and Mexico this basaltic soil has been under cultivation for 200 years, and does not seem to lose its marvellous fertility. The Pima Indians are known to have cultivated the same lands in Arizona for 500 years, and yet they remain wonderfully productive. The waters from the mountain streams constantly add rich materials to the irrigated lands, and prevent the necessity of ever using artificial fertilizers. The following tables are analyses made by the Department of Chemistry of the State Agricultural College at Pullman, Washington. They show that these soils, from widely separated localities in Yakima County, are especially rich in lime, potash and phosphoric acid, the three constituents most essential to plant life:

	No, 1.	*No. 2.*	*No. 3.*
Insoluble silica	64·860	71·670	60·2070
Combined silica	10·185	5·110	18·2270
Soluble silica	·385	·180	·2100
Potash	·700	1·070	·4328
Soda	·700	0·350	·3739
Lime	1·448	2·000	1·2127
Magnesia	·991	1·340	·7880
Peroxide of iron	4·768	6·880	5·1586
Alumina	6·238	7·910	6·8906
Phosphoric acid	·224	0·130	·1007
Sulphuric acid	·129	·020	trace.
Chlorine	·014	trace.	·0058
Water, at 120° C.	1·125	1·510	3·4527
Volatile and organic matter	2·600	1·310	3·0195

There are many irrigation enterprises in the county, and of the 139,400 acres now under ditch, two-thirds were not available for cultivation in the spring of 1893. The financial depression of the last two years has militated against the settlement of the arid regions, and yet the cultivated area and the population of this valley have nearly doubled in that time.

The following table shows the size and cost of ditches, and the amount of land reclaimed and under cultivation:

Canal.	*Length in Miles.*	*Acres Reclaimed.*	*Acres under Cultivation.*	*Cost to Date.*	*Delivered Cubic Feet per Second.*
Gelah Valley Canal Co.	22	6,000	1,000	$84,000	40
Yakima Valley Canal Co.	16	3,000	700	65,000	25
Takoma and Yakima Land Co.	12	—	—	43,000	—
Natchez and Cowychee	7	3,000	3,000	14,000	28
Union Broadgauge and Shauno.	16	5,000	4,500	18,000	45
Moxee Canals (3)	33	5,050	2,500	41,000	140
Moxee Artesian Wells (8)	—	1,500	600	15,000	10
Yakima Investment Co.	42	50,000	10,000	600,000	700
Yakima Irrigating and Imp. Co. (3)	51	17,700	1,100	100,000	329
Prosser Falls Irrigation Co.	8	3,000	400	42,000	28
Prosser-Priests Rapids	18	—	—	72,000	—
Ahtanum Valley (small canals)	100	16,000	16,000	25,000	100
Natchez Valley " "	12	8,000	8,000	6,000	80
Wenas Valley " "	8	4,800	4,800	7,400	36
Cowychee Valley " "	12	4,000	4,000	6,000	35

Nearly all the above are community ditches—that is, the farmers under them have stock in proportion to the number of acres of land which they own, and the service of water is gauged accordingly. A small annual assessment is made to provide for repairs and to hire a ditch-tender. Of course,

the farmers elect their own officers, who have complete charge. The Yakima Investment Company is the principal exception. It owns one of the largest canals in the United States, being thirty feet wide at the bottom, sixty-two feet at the top and over forty miles long. It covers some 50,000 acres in what is known as the Sunnyside, on the east side of the lower Yakima, and takes its water from that river. The annual charge for water is $1.50 per acre. There are no reservoirs in the county, and all are gravity ditches, except the one owned by the Prosser Falls Irrigation Company. This company utilises a small part of the power of the falls in the Yakima, about fifty miles from its mouth, to run two mammoth pumps to elevate sufficient water 100 feet to fill its canal and to irrigate 3,000 acres.

The long, warm summers, with the richest of soils, constant sunshine and abundant water, cause all the products of the temperate zone to thrive luxuriantly. This valley will produce everything that is raised in Southern California, except the lemon and orange, and possibly the fig. The prune, plum, peach, persimmon, pear, apricot, cherry, apple, and quince are grown to a size and with a flavor and keeping quality that is not excelled, if equaled, in any other locality. All kinds of trees are now (July 1st) loaded with fruit, and the limited experience of the past would seem to indicate that the fruit crop can be relied upon. While the trees have to be sprayed to keep them clean of the green aphis, the fruit itself is not attacked by any pests. The past success in growing it gives assurance that a large part of the valley will eventually be devoted to fruit. The quality of the variegated product should make the orchards quite as valuable as the orange groves of Southern California. Small fruits are equally productive, and melons excel in quality and quantity. Every vegetable raised anywhere in the United States can be produced here successfully. The asparagus and celery are especially fine. Potatoes grow to such size and are of such superior quality, that they bid fair to make the Yakima Valley celebrated for this product alone.

Wheat, rye, barley, corn, broom-corn and sorghum are

all grown, but the value of the land and the production of more profitable crops will always limit the acreage planted to them. As this is about the only locality west of the Rocky Mountains where corn can be brought to maturity, it will always be a fairly profitable crop. Alfalfa, the most ancient of all forage crops, thrives here to perfection. Its roots go down as far as water soaks, and, once started, it continues to yield permanently from six to eight tons to the acre annually. As a forage plant it has no superior; none has greater fat- or milk-producing qualities, and all stock thrive upon it remarkably. As the surrounding hills and mountains are covered with bunch grass,cattle and sheep are fattened on the ranges ten months of the year, and fed alfalfa the remaining two months. Horses, also, do well upon it,

The Yakima Valley probably excels any other locality in the world in the production of hops. The quality is very superior, and the yield per acre about three times that of the fields in New York. The hop louse or aphis troubles all other districts, and necessitates large expenses for frequent spraying. Here the hot sun and dry atmosphere kill the pest early in the season, and it does no injury. The average yield is about 1,700 pounds per acre, but with good cultivation it can be increased to a ton. The large yield, superior quality and relative low cost of production would seem to insure the future of the industry.

North Yakima, the county seat, is a beautiful town of about 4,000 people, centrally situated near the Yakima River, and with all the principal valleys radiating from it like the spokes of a wheel. It is laid out with broad streets and avenues, which are lined with shade trees, and about thirty miles of streams of clear, cool water flow along by the sidewalks. The city has good water-works, an excellent sewerage system and is lighted by electricity. There are eight churches, two large brick school-houses, and several hotels. The business portion is well built up with substantial brick blocks, and a number of stone buildings are now being erected. A quarry of excellent light-colored sandstone has recently been opened in the vicinity, and it is probable that

it will be largely used in the future, both on account of cheapness and appearance. The Commercial Club has commodious quarters and over 100 members. The professions are well represented, and there are four weekly newspapers. As showing the thickly-populated suburban districts, it can be stated, that there are ten school-houses within two miles of the city. North Yakima and the county generally are settled by a superior class of intelligent Americans from the Eastern and Middle States, who have come here to make comfortable, enjoyable homes. In consequence, the social features, schools and churches are quite equal to those in the older communities in New England. There are several small towns in the county, the principal one of which is Prosser, situated at the falls of that name. On account of its situation and manufacturing facilities, it bids fair to become an important place.

The county had a population of 4,500 in 1890, and it has trebled in the last five years.

NORTH YAKIMA, WASH., July, 1895.

ENGINEERING EDUCATION AND THE STATE UNIVERSITY.*

BY WM. S. ALDRICH, University of West Virginia.
(Member of the Society.)

Engineering education is an education for a profession. As such, its first requirement is a liberal education. This broad trend is best given by the pursuit of those studies affording mental discipline while developing a love of learning for its own sake, and capable of giving an added grace to the exercise of future accomplishments. The professional education follows in course. Its distinctively technical features are to be combined with practical work of an educational value. Such will be found in selected exercises and activities from among those required in professional life

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* Abstract of a paper read before the Society for the Promotion of Engineering Education, and revised for publication in the *Journal*.

—in office, field, shop and laboratory. Engineering education, while in the domain of science and an art, is itself an art and a science.

ENGINEERING EDUCATION IN A UNIVERSITY.

With these and related considerations before us, it may be inquired whether any one or all of them find a proper environment in a university. Will engineering education thrive in a university atmosphere, or will it be frozen to death? University presidents and renowned engineering professors have so placed themselves on record in this particular that we would fear the fate of any engineering training given within the walls of a university. But what are the facts as we know them to exist in the United States? Education for engineering as a profession has not only been recognized as entitled to, but has actually received and been correspondingly benefited by, a university environment, quite as much so as in the case of law and medicine. After finishing his liberal education, many believe that the student should continue in the university atmosphere while pursuing his technical studies. If there is any variation in the education itself, as well as in its product, it may be desirable or otherwise, according to the emphasis given academic, compared with technical training. Conclusions from first principles and known facts are important when drawn irrespective of known disturbing elements. In no other kind of education will financial considerations enter to change so completely every condition, and alter so entirely every product as in engineering education.

FEDERAL AND STATE AID TO HIGHER EDUCATION.

The extent to which such aid has been given is now matter of history, but educational history,* that is so important and so vital to our subject that any presentation within these brief limits would not be satisfactory to all. The duties and responsibilities of the State in this direction

* "Contributions to American Educational History, No. 9.—The History of Federal and State Aid to Higher Education." By F. W. Blackmar, Ph D. Bureau of Education, Washington, D. C. 1890.

have always been recognized, but chiefly in providing for academic training. Aside from the Government naval and military academies, technical education* received the most promising encouragement from private benefactions till its national endowment by the passage of the famous Land Grant Bill, July 2, 1862.† There were peculiar conditions of national life and growth of educational ideas which led up to the passage of this bill, avowedly for the promotion of scientific and industrial education, rather than what we have considered to be purely technical—much less, professional—from an engineering standpoint.

THE LAND GRANT ACT OF 1862.

The "Colleges of Agriculture and the Mechanic Arts," established pursuant to the provisions of this Act, mark the beginning of a new period and of a peculiarly American development of national aid for promoting scientific and industrial education. Each State received a definite "grant" of 30,000 acres of public lands for each Senator and Representative in Congress—an apportionment probably as equitable as could have then been devised. Differences of population at the time of the "grant" and the natural inequalities of statecraft have shown the folly of some States and the wisdom of others in disposing of their "land scrip." The proceeds were for "the endowment, support and maintenance of at least one college, where the leading object shall be—without excluding other scientific and classical studies, and including military tactics—to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the Legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

Agricultural education languished in many States; in-

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* "Technical Education in the United States." By Prof. R. H. Thurston. Paper presented at the Chicago meeting (July, 1893) of the American Society of Mechanical Engineers. No. DXLIII, vol xiv, of the *Transactions*.

† "History of the Agricultural College Land Grant Fund of July 2, 1862." Ithaca, N. Y. 1890. Publication of Cornell University.

struction in the mechanic arts had not yet developed into a science, and its incorporation into such colleges was somewhat incomplete until endowed schools led the way; meanwhile, scientific, classical and military instruction carried the day. The degrees conferred were those of Bachelor of Arts and Bachelor of Science. It will probably be admitted that this bill stimulated private endowments for technical schools, quite as much as it directly benefited engineering education. When mechanic arts or shop training became developed along lines at all educational, about the time of the Centennial Exhibition, it was too late for almost all of these institutions. First cost and yearly maintenance confronted them on the one hand; and, on the other, the conservatism of the management and faculty of these institutions, many of which were already living fully up to their incomes in maintaining the scientific, classical and military instruction required by this Act of 1862.

THE MORRILL ACT OF 1890.

By this second national endowment engineering education is recognized and some form of its development made possible in all of the land grant institutions. Aside from instruction in agriculture and the English language, the remaining branches specified in this Act are: "the mechanic arts, * * * * and the various branches of mathematical, physical, natural and economic science, with special reference to their applications in the industries of life, and to the facilities for such instruction." It seemed destined to endow and maintain courses in the mechanic arts at least. Engineering laboratories appeared in view, and some portion of the annual appropriation might be allotted for maintenance of instruction in this newly-required branch of experimental engineering. If the former Act of 1860 was ahead of its time in seeking to provide for instruction in mechanic arts, surely the latter Act of 1890 was not at all so anticipative of the next development of technical education — that of experimental engineering.

This endowment is from the proceeds of public lands, which the Federal and not the State Government has the

disposition of. Each State receives an equal amount annually, irrespective of population or the possibilities of State development. From the first installment of $15,000, made June 30, 1890, it is increased by $1,000 each year for ten years, after which it is to be maintained at $25,000 annually. These radical differences in the form and bestowal of the two national endowments are not without reason. This fund was for "the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts," established under the provisions of the Land Grant Bill of 1862. There are only two ways to realize this: (1) by increasing the salary account; (2) by providing additional facilities for instruction such as apparatus, machinery, text and reference books, stock and material.

The salaries of certain chairs, formerly paid out of State appropriations, have been found to be legitimately payable out of this Morrill fund, as the instruction given by the occupants of such chairs falls within that provided for by the bill. Finding that certain salaries *could* be so drawn did not carry with it the least obligation that they *should* be so paid. The land grant institutions of such States do not receive "more complete endowment." It is increased from Washington but decreased from the State Capitol to the extent of those salaries so paid. It is the State Treasury or some other institution which thereby receives "more complete endowment." In the same year that this was done hundreds of thousands of dollars were appropriated by the Legislature of one and the same State for an insane asylum. Pounds of cure: ounces of prevention. Will not our States suffer from this untoward and unanticipated development of parasitism? In particular, will not engineering education lack the encouragement and development it was destined to receive from this Morrill Act?

The duty of the State, after providing for the liberal education of the young engineer in its land grant institution, is to apportion its resources and adapt its facilities for his technical training so as to best prepare him for the particular professional demands that will inevitably be made upon him in his own State. Now, the parasitism, in refer-

ence to the Morrill fund, is not only most likely to occur, but actually has occurred in just those State institutions in which some such development of old and beginning of new engineering courses had long been deemed the necessary first step towards educating their own sons to develop the State's resources and share in the promotion of its industrial progress.

Distinctions of race or color made by any State in the admission of students to its land-grant institution, will require that State, by the provisions of this Morrill Act, to make "a just and equitable division of the fund to be received under this act between one college for white students and one institution for colored students." This means two faculties, a double equipment and a separate establishment throughout.

Such States need, for developing engineering education,all that the Morrill fund will legitimately provide. If they wish to establish and maintain reputable technical courses, to provide recognized facilities for practical work and experimental engineering, to justify their sons in seeking professional training in their own State institution rather than elsewhere, by offering an engineering education that will be at all comparable to that of other State institutions, the Legislatures of these States will need to make additional appropriations. In some of these States this will be all the more difficult, by reason of the parasitism that has developed already from a spirit of retrenchment in aiding educational work.

Engineering education is much less promoted by the Land Grant Bill of 1862, than by the Morrill Act of 1890, for two principal reasons: (1) The classical and the military instruction provided for by the former are excluded by the latter; (2) instead of the unequal permanent endowments of the former there is an equal annual appropriation given to each State by the latter. The effect of this favorable difference has been felt already in several of the States. It has stimulated private benefactions for the promotion of engineering education. It came, also, at a time when urgently needed to assist in establishing new and rapidly

growing engineering courses and aid in the material equipment for the same, such as in electrical engineering.

STATE AID TO ENGINEERING EDUCATION.

The least the State could do in accepting the Federal endowments was to meet the simple requirements of the law, to purchase, erect and maintain suitable buildings in which the instruction provided for by the general Government could be materialized. The initial and other building appropriations, as well as such made for increasing the facilities for instruction and providing for continued effective maintenance, have placed some of the original land grant colleges and universities in the very front rank among our State institutions.

The establishment of light, heat and power plants by some of the States in their institutions has rendered very material aid to engineering education. These were formerly urged from business reasons alone, such as securing greater economy of installation, maintenance and supervision. It as soon became evident that it would be a great advantage to have all the equipment of such a plant gathered about the engineering shops and laboratories, increasing still further the economy. Not only so, but this whole equipment thereby becomes available, at any time during the college year, for experimental engineering work. This might then be conducted on a more practical and commercial scale than if simple experimental machinery had been alone installed for such work. The State thereby reduces the current and contingent expenses for light, heat and power; and, at the same time, provides admirable facilities for shop and laboratory training in electrical, steam and hydraulic engineering. State pride and competition will enhance still further the great economic and educational value of such power plants; and increased use will be found for light, heat and power as necessary facilities in the development of laboratory methods.

AGRICULTURE AND MECHANIC ARTS.

These have been inseparably connected in the minds of statesmen when planning and developing Federal aid for

such instruction. By the Act of 1887, however, each State sustaining a land grant institution receives $15,000 annually for the establishment and maintenance of an agricultural "experiment station." When it comes to the question of Federal endowments for the promotion of scientific research, statesmen are divided. The direct aid which the "experiment station" has rendered to scientific agriculture has scarcely been less than its indirect benefit to agricultural education. The rapid growth of experimental engineering within the last decade, its recognized value for the determination of engineering data and precedents, its incorporation into the professional courses of almost all American technical schools, bespeak a like consideration for engineering "experiment stations" or laboratories in connection with all land grant institutions.

ENGINEERING "EXPERIMENT STATIONS," OR LABORATORIES.*

The technical equipment of such a laboratory would be of invaluable service in engineering instruction; and this in addition to that of the light, heat and power plant, which it is the duty of the State to establish. Engineering instruments would be standardized and tests of power plants con-

[* Considerable progress has already been made in Germany in the establishment of Mechanical Testing Stations, under the superintendence of a government board. *Engineering* (London) July 19, 1895, in describing "The Mechanical Testing Station at Charlottenburg," accounts for the popularity of the system among manufacturers and buyers on the ground that all articles are tested by competent and impartial men at moderate charges. It is held in equally high esteem by men of science for the prosecution of elaborate investigations requiring costly apparatus. "An official testing station is now to be found in every larger German town, in connection with its university or technical school. Some towns can boast of more than one technical college, and of more than one testing station. * * * Pamphlets are issued, stating the way in which specimens should be selected, handled, packed, etc. They also give a summary of the various tests in use, and the charges made for these. * * * By request, experiments are conducted on the special lines desired; the certificate issued in such a case contains a notification to this effect. * * * The same facilities are offered to firms which frequently consult the testing station. * * * Since 1889, the supervising board of the Prussian testing stations has published 'Mittheilungen' on the work done and the experience gained. These journals contain valuable information, and the apparatus originated in these laboratories can be freely copied."—EDS.]

ducted by disinterested parties. Engineering practice throughout the State would be reciprocally benefited; State laws relating to boiler explosions and engineers' licenses subject to careful supervision; and the duty of the State in protecting life and property from engineering accidents, casualties and negligence receive attention commensurate with that now given, by the agricultural "experiment station," to healthful foods, farm and dairy sanitation, and stock-raising. The State's resources of materials for building and other constructive work, as well as fuels—the prevention of their waste and the utilisation of by-products—would receive careful investigation.

Such a State engineering laboratory should be allowed the same immunities and granted the same privileges and opportunities as the agricultural "experiment station" now enjoys, in properly charging for tests, researches, trials, analyses and other scientific investigations. But beside this it should receive State aid for the publication and interchange of bulletins, quarterly or oftener; and this would add as much to the value and permanency of its year's work in engineering as is now done for the agricultural interests. The accumulation, classification and preservation of engineering literature; records of tests, researches and other investigations; and data for engineering practice and precedent, all would receive an amount of attention that it is almost impossible for individuals, corporations or manufacturing establishments to give. What has been accomplished already, by private munificence, in many of the above lines of engineering, in the shops and laboratories of a few of our leading technical schools, should be repeated, extended and made possible by Federal and State aid in every State college and university.

STATE AND ENDOWED INSTITUTIONS.

There are three classes of institutions in which engineering education receives more or less consideration:

(1) Those dependent entirely upon State and Federal aid.

(2) Those receiving private endowments in addition to Federal and State aid.

(3) Those dependent entirely upon private endowments.

For any particular branch of engineering in any one of these institutions the technical studies of the class-room will be found much the same, while the academic requirements differ widely. The kind and amount of practical work in office, field, shop and laboratory will vary according to the nature and extent of the endowment.

State institutions are created and maintained by the people. They exist for the greatest good to the greatest number of students. Candidates who are unable to enter the Freshman class cannot be turned away. In some of them, preparatory courses must be provided for those who have not had the high-school training of the cities. With few exceptions, tuition is free in all departments to all State students. All who pass the entrance examination must be received, whether faculty and facilities are commensurate or not. If both are alike insufficient, there is no better argument with which to go before the State Legislature for additional appropriations. However technical the instruction may be, it is necessary to bear always in mind the particular needs of the State in whose institution it is given; its natural resources, the traditions and customs of the people, their present and prospective industrial life, all, in fact, which make it necessary to shape engineering education so that it may best fulfil its mission in its own State rather than another.

Many State students enter for one or two years only; very few for a definite four-years' course. This entails a responsibility; but it is likewise an opportunity. More elementary technology in the first two years would open the young man's eyes, arousing an ambition to remain, or, perchance, to return after an absence occasioned by financial stress; and, during this period it would help the student better to earn a living. More practical work before leaving would relieve him of its equivalent after returning. Thus, to leave his educational work for a year or two is not the worst thing that can happen to the young engineering student. Many of them will be State cadets, receiving military instruction and training. This makes possible an

organization and development of practical work in engineering, along such lines as have been worked out at the naval and military academies, in detailing students for the conduct of engineering work, in office, field, shop or laboratory.

Endowed institutions are mainly supported by incomes from their first endowments and by tuition fees. They exist for the greatest good that they are able according to their several abilities to give to those who can pay for it. A high standard of admission may be set and maintained. If in good financial and professional standing they will take only that number of students best adapted to the faculty and facilities for instruction. All students enter for the regular four-years' course, practically by competitive examination. The technical instruction may be carried to any ideal standard. No respects have to be paid to any one community or class of interests, ensuring a purely professional course, with the corresponding degree.

STATE COLLEGES AND UNIVERSITIES.

State colleges of agriculture and the mechanic arts appear capable of a higher development, along certain lines, than the State university. In the former the funds are not apportioned among so many different departments as in the latter, whose aim is too often so to multiply courses as to be worthy at least of the name of a university. Each institution has peculiar advantages and disadvantages from the standpoint of engineering education. The State college is distinctively a school of science. Its courses are arranged, its equipment selected and its faculty appointed with this one object in view. In this respect it approaches the position of the endowed school of science. To add an engineering course in such is to introduce its purely technical features.

In both institutions, old academic courses are abridged to make room for the new engineering studies. The effort is made so to combine the essential requirements of a liberal education with sufficient technical training as to warrant conferring the degree of Bachelor of Science in

Engineering—a combination peculiarly significant of the development of engineering education in our land grant institutions. As State colleges and universities receive endowments equally from the Morrill fund, it would appear that, other things being equal, the college student might in time have larger equipment and more specializing facilities to work with. Such material advantages, however, may be more than offset by his lacking the liberalizing tendencies of the university environment.

FACULTY ORGANIZATION FOR ENGINEERING EDUCATION.

The introduction of engineering education into a State college or university—whether prompted by the ambition of the institution or demanded by the people—will require an organization, pursuant to the Morrill Act, which will be effected by an infusion of new ideas, new methods, new men and new appliances. It cannot be otherwise and succeed. In the evolution of engineering education in the State university, three distinct stages of organization of the teaching staff may be recognized:

(1) Engineering teachers are members of one common faculty under one president.

(2) They are organized as an engineering faculty, similar to the law and medical faculties which usually exist at this period of development.

(3) The organization of the engineering college within the university, with its dean or director, whose duties are related to this college as those of president to the university.

The faculties of State institutions are much less stable than in endowed schools. Aside from political causes, the reasons are obvious. There are engineering ethics and equities in teaching as well as in the practice of the profession. Marked changes are taking place in the development of all educational work. For the governing board to direct the president to distribute the studies among the several professors is to develop such an institution on the plan of the country school, where any man may be expected to teach anything at any time. The most efficient professional

teaching can be done and the most highly developed product obtained by specialization of supervision and thorough departmental organization, of which that of the engineering faculty is the first step in the right direction. The engineering college is a plan of organization falling into line with a form of university management which has been remarkably successful in other branches in European universities. In our State universities, engineering education admits of such an ultimate ideal organization, in which a few have already taken the lead.

ENGINEERING EDUCATION IN A NATIONAL UNIVERSITY.

The national endowments of 1862 and 1890 may alone be sufficient to enable several State institutions to get a start in at least one branch of engineering education. It may be regretted that this is the only source of income for such education in many of them; still, it has been shown that very substantial aid may be rendered by the State in furnishing buildings and in the establishment of a light, heat and power plant for its institution. On the other hand, if these Federal endowments are diverted into other channels, serving to maintain several courses in a university instead of a few in a college, or for an unusual development of agricultural education, or to pay salaries formerly paid out of State appropriations, or to sustain an institution of like grade for colored students, then the State appropriations for engineering education will require to be proportionately increased.

A new national endowment for engineering "experiment stations" or laboratories, to be established in all land-grant institutions, after the manner of the agricultural "experiment stations" (provided for by the Act of 1887), would supply the greatest need of all such institutions, namely, facilities for experimental engineering; and this, in addition to the other reason which has called such "experiment stations" into existence: the value of Federal aid for the promotion of independent scientific research.

The federation of all State colleges and universities into a national university, with its educational centre at Wash-

ington, would place such an institution in the very midst of the most favorable environment for the prosecution of that kind of advanced educational work for which it came into existence.

A select committee approved unanimously and recommended for passage (March 3, 1893) the Senate Bill 3,824, reporting as follows:

"Such an institution only could in any proper sense complete the now incomplete system of American education and most wisely direct all worthy efforts in the field of original research, and utilize the facilities for it so rapidly accumulating at Washington.

"It provides for the establishment of a university of the highest type, resting upon the State universities and other institutions of collegiate rank as they rest upon the high schools and academies—a university whose facilities shall be open to all who are competent to use them, but whose degrees shall be conferred upon such only as have already received a degree from some institution recognized by the university authorities; . . . and, whose several heads of departments are to have advisory and coöperative relations with the heads of Government bureaus for the mutual advantage of the Government itself and the cause of universal science."

AN ACCOUNT OF THE GARDINER LYCEUM, THE FIRST TRADE SCHOOL ESTABLISHED IN THE UNITED STATES.

By John H. Cooper.

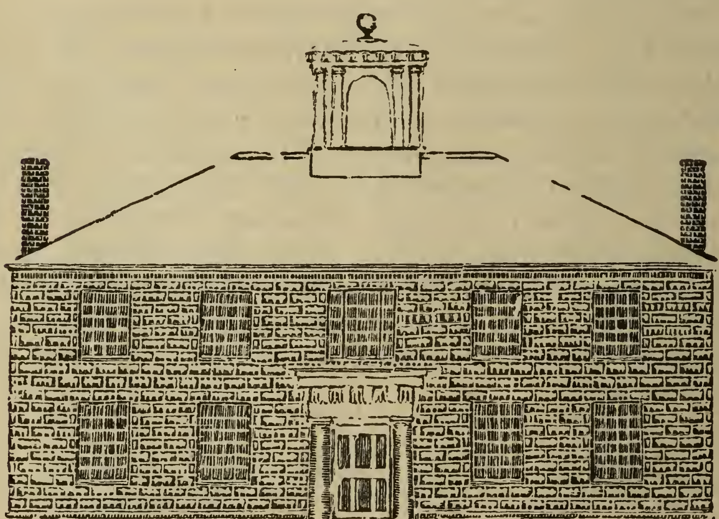
During a winter's sojourn in Gardiner, Me., the writer's curiosity was excited over certain printed and written records, which were placed in his hands by Mr. Geo. M. Holmes.

These records give authentic evidence of an early establishment in that town of a trade school, which was continued successfully for a number of years. The subject of enabling mechanics and farmers to become skilful in their

respective pursuits had occupied the thoughts of the promoters of this new scheme for years prior to a legislative act passed in the year 1821, which paved the way to a public declaration of their intentions, the erection of a stone edifice, and the organization of a school in the year 1822.

These facts place the Gardiner Lyceum first in order of time among trade schools established in the United States.

The originators of this school state that they knew of no organization in existence like the one they had in mind, from which to copy, and therefore they would be compelled to proceed altogether upon original lines.



The Gardiner Lyceum Building. Erected 1822—Burned 1870.

Ancient records teem with statements of results, but they do not always tell us how they were obtained.

From a study of these we are led to the conclusion that the arts and instruction in them very naturally began with the invention of devices and appliances for the collection and preparation of materials for food and clothing, followed closely by means of shelter from the elements and protection from enemies—insect, beast and man—all of which demanded scheming and skill of hand. "Solely intent (says

Rollin) upon the necessities of life, the first inhabitants of the earth did what new colonies are obliged to do."

We have good authority, but have not the space herein at command, for making and commenting upon quotations derived from ancient history, since Bacon says: "The earliest antiquity lies buried in silence and oblivion excepting the remains we have of it in sacred writ."

The writers of these initial chapters have not sounded a single note of preparation for technical work; they come at once, like a creation, to the statement of accomplished facts, leaving our common, enlightened intelligence to draw the inference from our own experience, which may be expressed in few words: "They that *do* shall know."

The history of the human race also abundantly proves the necessity of using head and hands, which are endowed with wonderful and infinite possibilities.

Man was not made for thinking alone; the necessities of existence are ever demanding that hand-work shall co-operate with head-work.

If any one wishes to make something, or to learn an art, there is no question that the best way to do it is for himself to do all the thinking and working necessary to a complete understanding and finishing of it. Bacon has wisely said: "We must familiarize ourselves with things themselves."

Beginning to live, even in our age, we must start with work upon the soil and in house-building, with introduction to the cognate branches of wood- and metal-working, and so the Gardiner Lyceum, recognizing the necessity of better domestic comforts and of advanced knowledge, starts at once the formation of classes in practical farming and carpentry, with promise of expansion into the larger fields of agriculture and architecture, as way may open, and which may be best adapted to the growing needs of their State.

Without further comment, we may now permit the projectors of this first trade school to speak for themselves. Their words have a clear ring, they are single and forcible to the subject, and are full of desire to be broadly useful.

They reached and adopted methods of instruction not even yet surpassed, as they ordained the establishment of a

museum of best working models, economical and practical ways of domestic management, the completion of knowledge by co-operative experimental processes, and moral control by individual responsibility.

Their inaugurals might be read with advantage at the opening of every technical course of instruction in our schools of to-day.

They have sounded the one leading permeating note, present in all our teaching of the science of business and life—the necessity of acquiring expertness of hand with brightness and breadth of intellect.

These early outcroppings of desire—sturdy of growth and full of promise—deserve more than a passing notice, forming, as they do, the safe and solid basis upon which the superstructure of trade, business and the activities of life depend.

If biblical writers thought well enough of trades and tradesmen—"the honorable of the earth"—to salute them with distinctive name and signal notice in their sacred treasury of the Divine word, approved and certain shall we be in transmitting the substance and record of their deeds to the train-teaching of new minds. Wise, indeed, are we, if in our day we plant the seed in good soil and nurture it to a ten-fold and a hundred-fold increase.

PETITION TO THE LEGISLATURE OF THE STATE OF MAINE, FOR THE INCORPORATION OF THE GARDINER LYCEUM.

To the Honorable the Senate, and the Honorable the House of Representatives, of the State of Maine, in Legislature assembled:

The petition of the subscribers respectfully represents that a donation has been offered of land lying on Kennebec River, in the town of Gardiner, estimated at $4,000, for the purpose of establishing within said town a school for teaching mathematics, mechanics, navigation, and those branches of natural philosophy and chemistry which are calculated to make scientific farmers and skilful mechanics. And whereas, it is an object of very great importance to any State, but especially one possessing fine rivers and a fertile soil, numerous mill seats and a coast indented with many and capacious harbors, to a State rapidly increasing in commerce, agriculture and manufactures, that its artisans should possess an education adapted to make them skilful and able to improve the advantages which nature has so lavishly bestowed upon them: And whereas, the State of Maine is in possession of those numerous privileges, yet while she has liberally fostered her colleges

for educating young men for the learned professions, and possesses numerous academies for preparing youth to enter those colleges, and for making useful schoolmasters, she has hitherto omitted to make provision for giving instruction to her seamen, her mechanics and her farmers, upon whom the wealth and prosperity of the State mainly depend. The recent improvements in chemistry, which give the knowledge of the nature of fertile and barren soils, and the best mode of improving them, render the importance of a scientific education to her farmers much greater than at any other period. Your memorialists would further represent that they consider the situation selected for this school extremely advantageous, from its central position in a populous neighborhood, in a fertile country, where provisions are abundant and cheap, where commerce is continually extending, and in a town possessing uncommonly fine mill seats and rapidly increasing in population. They would further represent that, in addition to the donation above referred to, a sufficient sum has been subscribed for erecting a convenient building for the above school; but as a considerable sum will be required for the purchase of instruments necessary for such a school, and as the fees of instruction (in order to make the school generally useful) must be much too low without the income of some permanent fund to give a comfortable support to a person adequate to the task of instruction, they must rely upon the patronage of the State for the power of carrying this plan into effect, notwithstanding the efforts which have already been made.

They therefore pray your honorable bodies to incorporate a school for the above purpose, with a body of seven trustees, with the usual powers and privileges, to be called the Gardiner Lyceum, and to grant such aid as will enable the trustees to bring the school into immediate usefulness.

R. H. Gardiner,	Edward Swan,
Peter Grant,	John Stone,
Simon Bradstreet,	Frederick Allen,
Richard Clay,	Sanford Kingsbery.

ACT OF INCORPORATION, PASSED BY THE LEGISLATURE OF THE STATE OF MAINE, JANUARY 30, 1822.

CHAPTER CVIII.

AN ACT TO INCORPORATE THE TRUSTEES OF THE GARDINER LYCEUM.

Section 1. Be it enacted by the Senate and House of Representatives, in Legislature assembled,

That an institution, designed to prepare youth, by a scientific education, to become skilful farmers and mechanics, be established in the town of Gardiner, to be called the Gardiner Lyceum; and that Robert Hallowell Gardiner, Peter Grant, Sanford Kingsbery, Frederick Allen, John Stone and Edward Swan, Esquires, be and they are hereby incorporated into a body politic, by the name of the Trustees of the Gardiner Lyceum; and that they and their successors shall be and continue a body politic and incorporate by the same name forever, with all the privileges, and subject to all the liabilities of other similar corporations; and that the number of said trustees shall never be less than five, or more than nine, four of whom shall constitute a quorum for the transaction of business.

SEC. 2. Be it further enacted, That the said trustees shall have power, from time to time, to elect such officers of said corporation as they shall judge necessary or expedient; and shall fix the tenures of their offices; to remove any trustee who may neglect to fulfil the duties of his office; to determine the method of electing said trustees; to fill all vacancies which may arise in said corporation; to determine the manner of notifying their meetings, the time and place where they shall be held; to prescribe the powers and duties of all officers and instructors of said Lyceum, and the course of studies which shall be therein pursued, and the qualifications necessary for admission thereto; *Provided*, that suitable instruction shall always be afforded to those classes of persons for whose peculiar benefit this institution is designed. And said trustees shall have further power to make and ordain any rules and by-laws, with reasonable penalties, for the good government of said Lyceum; *Provided*, that they are not repugnant to the laws of this State.

SEC. 3. Be it further enacted, That the lands, moneys, or other property, which have been already given, offered or subscribed, or which shall be hereafter given, granted, devised, bequeathed, transferred, or assigned to the said trustees, for the purposes aforesaid, or either of them, shall be confirmed to the said trustees and their successors in trust forever; and the said trustees may have and hold, in fee simple, by gift, grant, devise, bequest or otherwise, any land, tenements and hereditaments, and other estate, real or personal; *Provided*, that the clear yearly income thereof shall not exceed the sum of six thousand dollars; and may sell and dispose of the same, and apply the rents, issues and profits thereof in such manner as said trustees shall deem most advisable to promote the design and prosperity of said institution.

SEC. 4. Be it further enacted, That said trustees may have a common seal, and that all deeds sealed therewith, signed, delivered and acknowledged by the secretary of said Lyceum, by order of the trustees, shall be good and valid; and said trustees may sue and be sued, in all actions, real, personal or mixed; and may prosecute and defend the same to final judgment and execution by their said name of incorporation.

SEC. 5. Be it further enacted, That the Legislature of this State (of Maine, G. M. 26) shall have the right to grant any further powers to the said trustees, and to alter, limit or restrain any of the powers vested in them, as shall be judged necessary to promote the best interest of said institution.

SEC. 6. Be it further enacted, That Robert Hallowell Gardiner be and he is hereby authorized to call the first meeting of said trustees, by giving notice of the time and place of said meeting in some public newspaper, printed in the county of Kennebec.

Board of Visitors, appointed under Act of February 6, 1823:

The Governor, Albion K. Paris; the President of the Senate, the Speaker of the House of Representatives, and the following gentlemen, appointed by the Governor: Rev. William Allen, D.D., Brunswick; Rev. Jeremiah Chapem, D.D. Waterville; Hon. Daniel Cony, Augusta; Hon. Benjamin Vaughan, Hallowell; Hon. Ebenezer T. Warner, Hallowell; Hon. Enoch Lincoln, Paris; Thos. G. Thornton, Esq., Saco; Parker Cleavland, Esq., Brunswick; William Ladd, Esq., Minot; Josiah Hook, Jr., Esq, Castine; Nathaniel Gelman, Esq., Waterville.

AN ADDRESS TO THE PUBLIC FROM THE TRUSTEES OF THE GARDINER LYCEUM, BY R. H. GARDINER.

"It will doubtless be remembered by the citizens of this State, that at the last session of the Legislature an institution was incorporated by the name of the *Gardiner Lyceum*, the object of which was stated to be: 'To give to mechanics and farmers such a scientific education as would enable them to become skilful in their professions.' The trustees, having begun an edifice of stone for the use of the Lyceum, and having made arrangements for the commencement of instruction the ensuing winter, think proper to give to the public a more detailed account of the origin of the institution, and of the plan upon which they mean to proceed. The small number of mechanics acquainted with those principles of natural philosophy, upon which the successful operation of their arts depends, has been long a subject of regret.

"To supply this deficiency was the object of the projectors of the Lyceum, and although there was no existing institution to which they could refer as a prototype, yet they felt a confidence that their views were so practical, and so obviously useful, and so easily carried into effect, that they must meet with the approbation of the public. Nor have they hitherto been disappointed. Having obtained what aid they could from the neighborhood where the institution was to be located, they stated their views to the Legislature, and the great benefits which they expected to be derived from the establishment of the Lyceum ; but at the same time the inadequacy of their own means to carry it into effect without pecuniary aid from the State.

"An act of incorporation was readily granted ; and the trustees, after mature deliberation, determined to do everything upon their part to carry the institution into effect, with confidence that the Legislature, having approved their object and encouraged them to proceed, would not suffer their exertions to be lost, or the public to be deprived of the benefits of so important an institution for want of its fostering aid. Their plan has likewise received the approbation of many gentlemen of intelligence, some of whom have been engaged in the higher departments of instruction themselves, and others of whom have visited the most celebrated places for education in different parts of Europe. They have all thought the institution much wanted, and that, if properly conducted, it could not fail of being highly useful, and of being the means of similar institutions arising in other parts of the country.

"The practical utility of science cannot be doubted in an age where its investigations have produced such astonishing improvements as in the present. There is scarcely an art which has not directly or indirectly received from it important services, for science must necessarily be the foundation of every art.

"Not that the arts originate in the speculations of the philosopher, or cannot be practiced without an acquaintance with science. On the contrary, they frequently owe their beginnings to accident, and the knowledge of the art is but the knowledge of a few insulated facts.

"These facts, observed by the man of science, led him to an investigation of their nature and the laws according to which they are produced. He discovers what is necessary and what is accidental in the process, and thus infers an easier and cheaper mode of arriving at the same result. * * *

"All the sciences which come under the name of natural philosophy are useful. A knowledge of mechanics, which teaches the laws of motion, the general principles upon which all machinery is constructed and operates, and the nature and laws of the various moving forces, is almost indispensably necessary to the practical mechanic who is charged with the care of the construction of machinery. In the construction, it will enable him to accomplish his business with more ease and certainty. The formation of the teeth of wheels and pinions, *e. g.*, so that machines shall neither be retarded by unnecessary friction, nor rendered irregular in their motions, which is difficult to an uneducated mechanic, is made perfectly simple and easy by science. The value of science is particularly felt by the mechanic when anything is to be accomplished out of the common course of his business. Instead of wasting his labors in guessing and trying ill-conceived experiments, the scientific mechanic knows at once where to direct his efforts, and can predict with some degree of certainty the result before the experiment is made.

"All machines are capable of modification and improvement, and it is not so much by the invention of new machines as by the modification of old ones that ingenious mechanics have rendered so much service to the public. * * * But a mechanic must be extensively acquainted with machinery, and the principles upon which it is constructed, before he is able, by slight alterations, to apply machines to new purposes, or so to simplify their construction as to bring into general use those that were otherwise too expensive.

"With a view to furnish to farmers and mechanics the education here represented as so useful, the Gardiner Lyceum has been established, and the course of study will be arranged with a particular reference to the wants of those classes for whose particular benefit it is designed. As soon as suitable apparatus can be procured, lectures will be given upon the sciences there taught, and the application of those sciences to the arts will be illustrated as fully as the nature of the lectures will admit. As fast as the funds of the institution will allow, models will be procured of the best machines employed in the useful arts. Specimens will likewise be collected of the natural productions of the country, as opportunity offers, and they will be deposited in a cabinet in the Lyceum.

"Candidates for admission to the Lyceum will be required to produce certificates of good moral character, and will be examined in the four fundamental operations of arithmetic. * * *

"No student will be required to attend to all the branches of instruction for the second year, but only those which are best adapted to his future wants. He will likewise be instructed in the practical application of the knowledge thus acquired to the particular art which he is to practice.

"Two years will complete what is deemed an essential course, but instruction will be afforded to those who wish to continue their studies another year.

"The price of tuition will be $8 a term. Four students of good talents, but needy, will be admitted without charge. Boarding and lodging can be obtained near the Lyceum at $1.50 per week.

"The trustees consider the location of the Lyceum in the town of Gardiner as peculiarly fortunate, from its central position, on a navigable river, in a populous neighborhood and fertile country, where commerce is continually

extending, and in a town possessing uncommonly fine mill privileges, and which already offers to the student in mechanics the exhibition of a greater variety of machinery moved by water than can be found in any other town in the State. In the first organization of an institution, so novel in its nature, it seemed necessary that the trustees should be selected from its immediate neighborhood, for the convenience of frequent meetings; but this necessity will no longer exist when the institution is fairly in operation; and for the purpose of obtaining the views of different classes of citizens, respecting the management of an institution of such general utility, the trustees have determined to petition the Legislature at their next session to enlarge the Board of Trustees, and to form a Board of Visitors, composed of gentlemen of respectability, but residing principally at a distance, before whom the proceedings of the trustees may be brought at stated periods, and confirmed, modified or annulled as they may deem proper.

"The trustees inform the public that the institution will go into operation early in January, under the auspices of the Rev. Benjamin Hale, recently a tutor in Bowdoin College.

"The trustees conclude their address with expressing their confidence that, as they are engaged in an object calculated to meet the wants of a State which possesses all the requisites for becoming great, and distinguished in agriculture, manufactures and commerce, they shall not want for the support and encouragement of the public. They are engaged in no private enterprise. They expect to profit no particular class of men, but to aid those who form the bone and sinew and muscle of the body politic. They aim at the public good and they hope for the public patronage. * * *

"*Agriculture.*—The trustees have been always desirous of having a farm connected with the institution, upon which the students, whilst enjoying salutary exercise, might practically acquire such a knowledge of agriculture as would be of use to them through life, and at the same time enable them, in an honorable way, to discharge, by their own exertions, part of the expenses of their board. * * * A donation of a small but valuable piece of land has recently been made to the institution near the Lyceum, well adapted to agricultural experiments. * * * As, however, it must be a year or more before the land designed for the farm can be brought into a state fit for agricultural experiments, the trustees wish to mature their plan fully, and have it approved by the Visitors, before they lay it before the public. They now give hints of their design, which will be modified as found expedient. The principal objects which the trustees have in view, in establishing the professorship in connection with a practical farm, are: (1) To give to the future agriculturist the knowledge of those principles of science upon which his future success depends, and to let him see them reduced to practice. (2) To furnish a beneficial employment as recreation. (3) To diminish the expenses of board; and, (4) To try a series of agricultural experiments adapted to the soil and climate of Maine. These experiments will be tried by the students, under the direction of the professor, and will be conducted with as much care and accuracy as the nature of the case will admit.

"The labor on the farm will be altogether voluntary. No student will be obliged to work unless he chooses, but it is presumed that even those who do

not intend to become farmers will find the labor on the farm a pleasant occupation, independent of every other consideration, and, in a moral point of view, the substitution of a pleasing occupation connected with the highest utility for the idle sports of their age, cannot but have an important influence on their future character in life.

"The trustees hope to be able to provide some suitable employment for those young men who may attend the institution with a view of becoming mechanics, by which they may be enabled to discharge their expenses.

"Another object of the trustees is to collect the best models of useful tools and machines. A room will be appropriated to these models, where they will be properly arranged and open to the inspection of the public.

"In conclusion, the trustees will only add that, as public good was the sole motive for establishing the Lyceum, so it is the governing principle in all its measures. The whole plan has been arranged with a single reference to the wants of the public, and encouraged as the trustees have been by the patronage they have already received, by the full approbation of gentlemen distinguished not only for science but for practical views, and by the interest which is kindling through our widely extended country in the improvement of agriculture, manufactures and the arts, they cannot but hope that the first school, which has been established for the express benefit of the farmer and the mechanic, will not be permitted by an enlightened public to languish for encouragement and support. "R. H. GARDINER, per order."

"*Gardiner, November, 1823.*"

"*Continued Progress.*—Since the last address of the trustees was presented to the public, several important measures have been adopted. * * *

"(1) With a view to accommodate those whose business during the summer precludes the possibility of their joining the regular classes in the Lyceum, the trustees have established winter classes, in which they can be taught those branches of science which may be serviceable to them in their respective employments.

"The winter classes already established are in *surveying*, in *navigation*, in *carpentry* and *civil architecture*, *chemistry*.

"(2) Relates to expenses, with suggestions towards reducing them.

"(3) One of the most important subjects which engage the attention of those who have the care of a literary institution is that of its discipline. The common methods, from some cause or other, are in a great degree ineffectual, and the fact that they are so, under the best instructors, leads us to suppose that something wrong exists in the very principle upon which they are founded.

"The method which the trustees have adopted admits the rights of students, and proceeds upon the ground that they have reason and a sense of propriety and of morality, which may properly be brought into use in their government. These principles are always adopted in some degree by judicious instructors, whatever their method. They are made the very foundation of our system. This system is new, and is to be considered as an experiment tried upon the responsibility of the trustees.

"* * * In schools in which the government is wholly in the hands of the officers, and the students have no part but to obey, they are often sub-

jected to regulations of which they are not taught the propriety, or which they consider as unreasonable, and the result is, they look upon their instructors as tyrants, whose laws it is heroism to disobey. Nor is this the worst consequence. The infraction of such laws must be punished, in order to support the authority by which they were made, and will frequently be punished with as much rigor as violations of moral precepts or religious duties, and these two kinds of offences, unlike as they are in their nature, will be classed together.

"It will be difficult to remedy these evils, where the instructors and students are supposed to have different interests, and are acting in opposition to each other. But we believe there are principles in our nature, which, if properly cherished and rightly directed, will lead young persons to use their exertions in favor of good order and good morals. * * * Their sense to honor is too often converted into a principle of obstinacy in their opposition to authority; but it might be so directed as to give firmness to conduct truly honorable. * * *"

"The system of discipline, adopted by the trustees, places a large share of the government of the institution in the hands of the students. It is republican in its spirit. A general committee is elected twice each term by the students, in which one of the instructors usually presides, and by which all the laws are enacted. The Principal has a negative upon these laws. They are carried into execution by officers chosen by the students.

"The trustees are inclined to expect much from this system. The students possess a knowledge of each other's character, which instructors cannot always obtain, but which is very necessary for forming just decisions. * * * The laws, being made by the students, will be thoroughly understood, and the consciousness that they are governed by regulations of their own will prevent all fear of oppression. The confidence which this system reposes in the student has the effect of elevating his character. The exercise which he has in self-government is favorable to a proper self-government in future life, and the part which he acts in this small community evidently prepares him to discharge his duty as a citizen of a free republic.

"The saying of Agesilaus, that 'youth should learn that which will be of most use to them when they become men,' must approve itself to every understanding. * * * We hope that the time is not far distant when it shall be as common for farmers and artisans to prepare themselves for their business by a suitable and thorough education as for lawyers and physicians.

"Such an education would not only lay a foundation for their success, but raise the character of their employments from mere mechanical labor to scientific pursuits, and give them credit which their usefulness merits.

"BENJAMIN HALE."

"*Gardiner, October, 1824.*"

"The trustees also give notice that, by arrangements recently adopted, the opportunities for improvement at the Lyceum are increased, and the advantages extended. Scholars may be admitted at the age of twelve years, and will be required to pursue their studies in a schoolroom, under the personal direction of one of the instructors, until qualified to advance into the higher classes.

"Means are also provided by which such students as chose may devote a portion of the time to earn their own support. It is not, therefore, necessary that a young man should be urged forward faster than his abilities and means will justify.

"A workshop is furnished, where employment will be given to young men desirous of supporting themselves, by which they will be enabled to do so in whole or in part. In the summer a number will be received who will have the opportunity of defraying the expenses of board by labor on the farm.

TUITION FEES.

"Classes in agriculture and in civil architecture and carpentry for the whole term, including fees for lectures, $12.00.

"Class in chemistry, including fees for lectures, $10.00.

"Third class, $5.00 per term.

"First and second classes, $8.00 per term.

"Tuition will be furnished gratis to any meritorious young men unable to pay.

"*Gardiner, November 8, 1827.*"

A letter by Mr. E. Holmes to Mr. P. C. Holmes, dated October 30, 1827, says: "We are making some arrangements to enable you of the 'chip' fraternity to pay for board and tuition by work. If you will come down, I shall want you to take charge of the shop and regulate the whole concern, while handling the tools. If you come, or if you don't come, I want you to look into that lathe which turns lasts, gunstocks and *bureaus.* * * *

"I have thought it would be an excellent thing in an establishment to turn spokes to wheels, studs to sleigh bottoms, etc., much more expeditiously than in the old way of shaving them out."

"GARDINER, January 2, 1828.

"The trustees of the Lyceum voted to give you the charge of the carpenter class while in the shop. The term commences to-day."

[NOTE.—This was addressed to Mr. Philip C. Holmes, the founder of the machine shop and gear works now conducted by his sons and others, in Gardiner, Me.]

"GARDINER LYCEUM,
"WINTER CLASSES, 1827–28.

"Classes in carpentry and civil architecture and in agriculture will be admitted November 22d, and a class in chemistry, January 2d, next, each to continue until the third Wednesday in April, 1828. * * * Such of the classes in agriculture and chemistry as desire it will have the privilege of attending with the professor in the laboratory during the preparation of the lectures."

We have not been able to learn definitely how long this school maintained an existence. The only reliable information bearing thereon is that conveyed in a private letter from Mr. Geo. M. Holmes, of the P. C. Holmes Company,

Gardiner, Me., to the author, from which the following extract is printed, viz.:

"The school seems to have been quite successful in its objects, so far as I can learn, during its existence. But it was evidently too far "ahead of the times," and so languished and finally was closed for lack of sufficient support and patronage. As nearly as I can ascertain, this occurred about the year 1832."

ELECTRO-METALLURGY AS APPLIED TO SILVER REFINING AND INCIDENTALLY TO OTHER METALS.*

By George Faunce, B.A.S.,
Superintendent Pennsylvania Lead Company.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

How swift is electricity! It hastens on its way with the speed of the lightning. When men began in earnest to investigate its laws, and to make practical application of it to the arts, it seemed as though they became infected sympathetically with this characteristic quality of *hurry*. For the past quarter of a century mankind has been racing tumultuously in the wake of this newest servant of humanity, in the endeavor to subjugate it to ten thousand different uses. Only yesterday it was harnessed to the chariot of human progress, and yet even at the start it is on nearly an even footing with steam. Every day new applications are being made, while old methods and forces are being abandoned.

To-day, a new electrical invention is announced; to-morrow, further progress in the art may render the first useless. Having occasion lately to repair a dynamo that was built about seven years ago, I learned that machines of that type were no longer made. It was hard to recall to mind that such a machine had ever been made; yet, to us, the machine had hardly worn off its novelty.

*A lecture delivered before the Franklin Institute.

It is just this rapid evolution and progress that makes it a thankless task to attempt to publish a book or prepare a lecture on the practice of one of the electrical arts. Before the ink is fairly dry, new inventions may have made the author's words ancient history. One can only catch and record an instantaneous photograph, as it were, of the present condition of the art, content with the prospect that, before it is exposed to public view, it may be behind the times, and interesting only as a bit of history.

It is needless to state that electricity is a wonderful and mysterious force; any attempt to explain its nature, or to give the theories by which the physicists attempt to explain it, would be outside the province of this lecture. Enough to accept it as a potent factor in our lives. You all know the varied ways in which it manifests its presence. It generates heat, sufficient to weld iron or smelt metals. It lights our houses and streets. It sends messages around the world. It carries our words, and very tones, hundreds of miles. It transports our bodies from place to place with a speed to which there appears to be no limit. It can do subtler things than these. At its magic touch, chemical affinities are overcome, and substances are split up into their elements. Thus it manifests itself in the form of heat, light, motion, chemical action, while it is said to aid the growth of plants—attempting to rival the sun in its life-giving powers.

This much by way of prelude. I will now enter upon the subject of the evening's lecture, which is the study of that one, among the various manifestations of electricity, on which the art of electro-metallurgy depends, namely, that force which causes the decomposition and recomposition of chemical compounds. This force is named *electro-chemical force.*

Metallurgy is the art of obtaining metals from their ores, and includes the refining and parting of metals, as well as the smelting of ores; in fact, all processes by which the metals are isolated or set free from accompanying impurities.

Electro-metallurgy, therefore, in its strictest sense, should be defined as the art of obtaining metals from their ores,

by the agency of the electric current. Unfortunately, until recently, the sole practical application of electricity to the isolation of metals has been in the separation and deposition of certain metals, from aqueous solutions of their salts, upon a prepared surface, as in the processes of electroplating and electrotyping. In these processes the finish of the plated articles, or the quality of the deposit, is of the first importance, and not the gaining of the metal.

The term electro-metallurgy, to most persons, is now synonymous with this kind of deposition. It would be better to call these processes *electro-deposition*, since the proper deposition of the desired metal on the surface of the article treated is the sole object aimed at; and to reserve the term electro-metallurgy for its correct signification as the art of recovering metals from their ores, and refining them, by electricity. In the first case, the nature and form of the deposit is everything. In the second case, these are secondary considerations, while the great desideratum is quantity and purity of deposit.

Historical Sketch.—One of the commonest and simplest forms of electro-deposition is shown when one metal is coated with another by simple immersion in a solution of a salt of the latter. For example, iron dipped into a solution of copper becomes coated with copper, while copper receives a deposit of silver when dipped in a solution of silver. Zinc, or aluminum, precipitates lead from its solutions, while lead in turn throws bismuth out of its solutions. The fact of the deposition of copper from its solution by iron is mentioned as early as the fifth century. Palissy, the potter, in the sixteenth century, describes the method of coating copper and iron with silver by immersion in silver solution. Sulzer, in 1752, noticed a taste like that of green vitriol when silver and lead in contact were placed on the tongue.

In 1790, two Dutch physicists decomposed water by means of electrical sparks (obtained by friction). In 1799, Volta made his famous discovery of the production of an electrical current by chemical action; and shortly after produced his "crown of cups," by means of which a continuous current could be produced.

All the curious facts known and noted up to this date had remained simply curiosities in the realm of science, and no practical application of them, so far as we know, had been made. From this time, however (that is, no longer ago than the beginning of the present century), investigators began to record results with increasing frequency, although two score years more were destined to pass before any of their discoveries should bear fruit in actual industrial processes.

I will rehearse some of the discoveries which bear directly on our subject.

In 1800, water was first decomposed by the voltaic current. In 1801, it was noticed that if silver were used as a negative pole in a solution of copper, the silver received a coat of copper which would stand burnishing. During the next few years various observers noticed the liberation of the constituents of various salts at the two poles of the batteries, and Brugnatelli gilded two silver medals, by making them negative poles in a gold solution. Sir Humphrey Davy, in 1807, deposited metallic potassium on platinum by means of a powerful current of 274 cells, which was passed through moistened caustic potash. In 1831, Faraday discovered magneto-electricity, on which discovery depends the principle of all the dynamo machines of to-day. In 1834, he formulated his law of electro-chemical equivalents, which will be referred to later.

In 1836, the Daniell cell for generating electricity was invented. It was the first two-liquid cell, and gave a very constant current. As it is the type of nearly all the batteries now in use, and affords an instructive illustration of the process of electro-deposition, it will be well to describe its construction and action. It consists of an external vessel containing a cylinder of zinc. Inside of the cylinder of zinc is a porous earthenware vessel, and inside of this again is a strip of copper. The inner porous vessel is filled with a solution of sulphate of copper immersing the copper strip. In the external vessel, and immersing the zinc cylinder, is dilute sulphuric acid. The acid slowly dissolves the zinc, forming sulphate of zinc and liberating hydrogen. The hydrogen passes through the porous clay vessel, displaces

the copper of the sulphate of copper, thus forming sulphuric acid. The copper, which is displaced from the sulphate, is deposited on the strip of copper which forms the negative pole of the battery.

From 1837 to 1840, electro-deposition, in the form of electrotyping and electroplating, was brought prominently into notice, and began to be used practically on the commercial scale. For several years, the deposition was performed exclusively by currents generated with batteries, but in 1842, Woolrich took out a patent for the first magneto-electric machine for generating currents for electro-deposition. From that date until 1866, no new principles in electro-deposition were discovered, but some progress was made in the improvement of machines, solutions and other details. In 1866, Elkington, in England, obtained a patent for refining copper by electricity, and this date marks the beginning of the application of the electric current to electro-metallurgy proper. The electrolytic copper refining industry has assumed immense proportions, and following hard upon it have come processes for refining silver-lead, for smelting aluminum and aluminum alloys, as well as numerous processes for extracting metals directly from their ores without the intervention of heat derived from fuel.

Principles.—Before entering upon a description of these processes, it will be well to give a very concise résumé of the principles underlying electro-chemical action.

(1) Whenever electricity is generated, whether by friction, by galvanic action, or by motion in a magnetic field, there is set up a tendency for the electricity to flow from one place to another; *e. g.*, from the positive to the negative pole. This tendency is strong or weak, according to the nature of the generating cause, and is measured by the capability of the current to overcome the various resistances opposed to its flow. This capability of overcoming resistance is called the electro-motive force. It is analogous to the pressure of steam, or to the force of a head of water. A certain E.M.F. will transmit a given quantity of electricity through a given resistance in a second. If the resistance be increased, the same E.M.F. will transmit a certain smaller quantity in a second, and *vice versa*.

The quantity of electricity which passes through a given circuit in a given time is a measure of the intensity of the current. The power of decomposing chemical compounds is proportional to the intensity of the current. Although it is true that a definite minimum E.M.F. is necessary before any decomposition will take place, when this limit is once reached, the quantity of material decomposed in a second will depend entirely on the intensity of the current, and not at all on the E.M.F., which may be increased to any extent without changing the rate of deposition.

The electrical resistance of a conductor of electricity is the property it possesses of impeding the flow of a current through it; that is, of diminishing the quantity of electricity that will pass through it in a given time, when urged by a given E.M.F. The resistance of a conductor is inversely proportional to its section and directly proportional to its length and to its temperature, except that with liquid conductors the resistance decreases with increased temperature. Compared with the metals, liquids have an enormous resistance. The best conductors among liquids have a resistance many thousand times greater than that of the most resisting metal. The relative resistance of liquids is decreased by the presence of acids or metallic salts. The practical unit of E.M.F. is the volt, and is very nearly equal to the E.M.F. of the current generated by one Daniell cell. The unit of intensity is the ampère, and is taken to be that current which will deposit in one second of time 1·12 milligrams of silver. The unit of resistance is the ohm, and is represented by a column of mercury about 3½ feet long and 1-25 inch square, at 32° F. A current having an E.M.F. of one volt, will transmit a current of one ampère through a resistance of one ohm in one second. Please keep in mind the meanings of these terms—volt, ampère and ohm—and note that the depositing power of a current depends not on the E.M.F., or voltage, of a current, but entirely on its intensity, as shown by the ampèremeter. I emphasise this because I have sometimes found it difficult to convince so-called electrical experts that a high voltage would not answer just as well for depositing purposes as the required number of ampères.

(2) The relation existing between these three factors in any current produced by a given constant cause, is embodied in what is known as Ohm's law, which is as follows:

The intensity of the current, C, is obtained by dividing the E.M.F., E, by the resistance, R, thus:

$$C = \frac{E}{R};$$

whence

$$R = \frac{E}{C},$$

and

$$E = C\,R.$$

By the aid of these formulæ, if any two of these factors are known, the third is easily found. Thus, if the ammeter shows the current through a given circuit to be 100 ampères, while the voltmeter shows an E.M.F. of fifty volts, it is evident at once that the resistance of the circuit is

$$R = \frac{E}{C} = \frac{50}{100} = \tfrac{1}{2} \text{ ohm}.$$

(3) It is essential, in preparing for any industrial process, to know the amount of work that is to be performed. We find that the work done by an electric current is equal, in kilogrammeters, to the product of the ampères by the volts, divided by g, the gravitational acceleration ($= 9{\cdot}81$), or

$$W = \frac{C\,E}{9{\cdot}81}.$$

For example, if a machine generates a current whose E.M.F. is 100 volts, and whose intensity is 200 ampères, it will perform work as follows:

$$W = \frac{100 \times 200}{9{\cdot}81} = 2{,}040 \text{ kilogrammeters};$$

or, as 75 kilogrammeters = 1 horse-power, the work performed will be 27·2 horse-power.

(4) When a current of electricity passes through certain liquids, it will decompose them. This operation has been termed by Faraday, electrolysis. The liquid in which the

decomposition occurs is called the electrolyte. The electrodes are the conductors immersed in the liquid, the anode being the electrode through which the current enters, and the cathode the one through which it leaves the bath. In order to produce electrolysis, the substance to be decomposed must be a conductor of electricity, and it must be a liquid; *i. e.*, either in solution or in a state of fusion. When decomposition takes place, the hydrogen, metals or bases, flow to the cathodes, while the oxygen, or acids, flow to the anodes. If the anodes are soluble, or attackable by the products of electrolysis, they will be gradually dissolved or oxidised. The accumulation about the anodes of the products of decomposition, and of the oxides formed from the metals of the anodes, interferes considerably with the efficiency of the current, on account of the resulting polarisation, and the tendency to set up currents in a direction opposite to the decomposing current. These effects can be partially prevented by constant agitation of the bath.

(5) Faraday, in 1834, gave us two important laws governing electrolysis:

(*a*) The quantity of substance decomposed in a given time is proportional to the intensity of the current (or the quantity of electricity passing through). A corollary of this law is that, in order to set free a given quantity of any substance, a constant quantity of electricity is required. These two quantities are electro-chemical equivalents.

(*b*) The same current acting at the same time on a series of solutions of various kinds will separate in each solution definite weights of the constituents in the ratio of their chemical equivalents. If, for instance, the current traverses tanks containing, respectively, water, lead acetate and silver nitrate, for each gram of hydrogen set free in the first tank, there will be found, respectively, 103·5 grams of lead and 108 grams of silver in the others.

Various causes operate to interfere with the action of these laws, notably, the secondary currents engendered at the anodes by oxidation, etc.

(6) The work absorbed in decomposing a given substance is equal to the work corresponding to the heat produced by

the recombination of the elements, or ions, of the decomposed substance to form the original compound. As one ampère will decompose constant amounts of an electrolyte with varying E.M.F., it follows that to electrolyse a given compound, it will be necessary to use a certain minimum E.M.F. Whatever be the quantity of electricity that passes through the electrolyte, no decomposition will take place until this E.M.F. is reached. Thus, for example, to decompose water an E.M.F. is required of nearly one and one-half volts; for chloride of zinc, two and one-half volts; for copper sulphate, one and one-quarter volts; for copper nitrate, one and one-sixth volts; for lead nitrate, one and one-half volts; for silver nitrate, only three-eighths volt, etc.

(7) When several metals are in the same solution, that one will be deposited first, which, under existing conditions, is most electro-negative.

The purity of the deposited metal depends on various other conditions, viz.: the acidity of the solution and the amount of other metals present in solution. These other more electro-positive metals are more likely to be deposited in a neutral or alkaline than in an acid solution, and if they are present in too large quantities, they will be thrown down with the negative metal. In a solution containing silver, copper and lead nitrates, the current will not deposit a trace of anything but silver if the proper amount of acid is present, unless the lead and copper get to be considerably in excess of the silver. There is no danger of the deposition of copper even when the solution contains one and one-half times as much copper as silver.

(8) When the anodes are soluble and of the same kind as the deposited metal, as is generally the case in refining by electricity, the work absorbed by the decomposition is exactly replaced by the energy produced by the solution of the anode, and the consequent regeneration of the electrolyte. But this does not mean that no work is required in these electrolytic processes. On the contrary, a large amount of work is absorbed in overcoming the resistance of the circuit, in making up for leakage of electricity, in counteracting polarisation and reversal of the currents, in work-

ing pumps, stirrers, etc.; so that the sum total of work performed, and consequently of power consumed, in these plants is very considerable.

With this very brief review of the facts and laws which directly affect electrolysis, you are prepared to follow me in a description of that process with which I am most familiar, and to take a glance at some of the other allied processes which have lately come into great prominence.

Moebius Process.—The process now in use for the electrolytic separation of silver and gold was patented by Bernard Moebius, about ten years ago. He installed his first plant in Mexico, where he perfected his process and proved its feasibility. He next introduced the process into the Kansas City Refinery; but for some unexplained reason it was very soon abandoned. The next to take hold of the new process was the Pennsylvania Lead Company, which, on the advice of its efficient superintendent, the late F. C. Blake, secured the sole right for the State of Pennsylvania, and erected a complete plant in 1886. The original plant consisted of 49 baths, guaranteed to refine 10,000 ounces of silver per day. Shortly after the completion of the original plant, the capacity of the establishment was doubled by the addition of 49 more baths, making the total guaranteed output 20,000 ounces of silver per day. The process was successful from the beginning and has worked smoothly and continuously, without a day's interruption, up to the present time. It has been so managed as to turn out twice as much as the guaranteed output, or 40,000 ounces per day, and this, with only 84 baths, which is the largest number that can be run continuously.

A small plant was in successful operation for a short time in New York City, but was abandoned, I think, for commercial reasons. Mr. Moebius has recently installed another plant at Piños Altos in Mexico, and has only just completed one at St. Louis. Thus, until very recently, the plant at the Pennsylvania Lead Works, at Pittsburgh, has been the only one in the United States in continued successful operation. And here a few words in explanation of the relative position of this process in the general work of the es-

tablishment. The primary object of the company was the production of refined lead suitable for corroding into white lead. Practically all the lead bullion now produced west of the Mississippi Valley carries more or less silver and gold. In refining the lead bullion, these impurities (for so they are to be considered) must be eliminated. Therefore, treatment of gold and silver becomes an essential part of the business of refining lead. The silver and gold are taken out of the lead by means of zinc, which, when intimately mixed with the lead, takes hold of the precious metals and bears them to the top of the bath. The resulting zinc-silver-lead alloy is skimmed off and subjected to a high heat, by which the zinc is distilled off and recovered by condensation, while the alloy of lead, silver and gold, left from the distillation, is cupelled. By the process of cupellation the lead is oxidised, being converted into litharge, which runs off the metal, leaving finally the alloy of silver and gold in the cupel. This silver-gold alloy (called doré bullion), it was formerly customary to ship to the New York Assay Office, where it was parted at a cost of one cent per ounce. Now it is taken to our own parting-room, which is merely an addition to the regular operations of the company. Although the process is of the nature of a side issue, it has enabled the company to undertake an immense business in the way of refining silver bars from amalgamating mills, and silver sulphides from lixiviation works, which could not have been handled economically without the aid of this, or some other parting process.

The silver is refined on the cupel until it contains not over two per cent. of impurities (lead, copper, bismuth). If more impure silver is treated, there is more or less bother with accumulations of copper and lead in the solutions, with consequent large amounts of by-products, and also increased difficulty in turning out a pure product. When the silver has attained the proper degree of purity, it is cast from the cupel into flat plates about 18 inches long, 10 inches wide and ½ inch thick, weighing 425–475 ounces troy (about 30 pounds avoirdupois). These form the anodes in the electrolytic operation. Each plate has three projections or lugs on one of the long sides. Holes

are punched in these lugs to receive the wires which suspend the plate in the solution. The three supporting wires ($\frac{3}{16}$ inch diameter) are attached to a copper rod 28 inches long and $\frac{1}{2}$ inch in diameter, and then the plates are ready to be placed in the tanks.

The ninety-eight baths are arranged in sets of seven, each set being styled a *tank*. These tanks are made of 2-inch California redwood plank, joined together very carefully. The bottom is lined with sheet rubber. Each tank is 11 feet long, 24 inches wide, and 20 inches deep (inside measure), each separate cell, or bath, being 2 feet long by 18 inches wide.

The electrolyte is a solution of nitrate of silver and nitrate of copper in dilute nitric acid. The acid present is only $\frac{1}{2}$ to 1 per cent. of the solution, as only just enough acid is used to prevent the deposition of copper. The consumption of acid is about one pint every twenty-four hours for each bath. The current is conducted to the baths through rods $\frac{5}{8}$ inch in diameter. The rods connecting the tanks are so arranged that any one or any number of the tanks may be left out of the circuit if desired.

The cathodes are thin sheets of pure silver, 13 x 20 x $\frac{1}{32}$ inches thick, weighing 50 ounces troy ($3\frac{1}{2}$ pounds avoirdupois). These cathodes are rolled in the machine shop of the company, from their own silver. In each bath, four of these cathodes are suspended, alternating with three anodes. The distance between cathodes and anodes is about $1\frac{3}{4}$ inches. The rods which support the cathodes and anodes themselves rest on the main conducting rods, which are arranged horizontally along the sides of the tanks. On the side of the bath where the current enters the anodes, the ends of the cathode wires are insulated by rubber, while on the opposite side the ends of the anode rods are insulated, while the cathode rods are in direct contact with the conductor.

The current from the dynamo has an intensity of 180 ampères. It enters a bath through three anodes, and is, therefore, divided up into three parts, each with an intensity

of 60 ampères. It passes out at each side of each anode, through the solution, to the cathodes, so that the intensity of the current through the solution is 30 ampères. These divisions of the main current pass out through the cathodes and are reunited in the main rod and carried to the next bath. The cells, or baths, are arranged in series, the whole current passing through each bath. Each anode is suspended in a muslin bag, which serves to collect the undissolved metals, which fall in the shape of a black slime. The metals thus caught are all of the gold and bismuth, the greater part of the lead as peroxide, together with some silver and copper. Below this system of anodes, cathodes and bags is stretched, on a box-like frame, a piece of cloth on which is gathered the deposited silver, as it is scraped from the cathodes by wooden "brushes." These brushes straddle the cathodes, hugging close to each surface without touching. They are kept moving to and fro by machinery, and they serve not only to brush off the silver as fast as it is deposited on the cathodes, thus preventing short-circuits, but also, by keeping up a constant agitation of the liquid, to prevent, to a large extent, polarisation and the tendency of the solution to settle into layers.

The principal points covered by the patents of Mr. Moebius relate to these mechanical stirrers, and the bags for collecting the gold slimes.

Now we will suppose that we are running 10 tanks, or 70 baths. The dynamo is made to generate a current of 180 ampères. The voltmeter shows an E.M.F. of about 90 volts. Then, by Ohm's law,

$$(R = \frac{E}{C}),$$

it appears that the resistance of the circuit is $\frac{1}{2}$ ohm, or about ·007 ohm for each bath. The work absorbed by this current is, by our formula,

$$W = \frac{E\,C}{9·81 \times 75} = \frac{180 \times 90}{73·58} = 22 \text{ horse-power.}$$

The total cathode surface per bath is 10 square feet. The current being 180 ampères, the density of the current will be about 18 ampères per square foot of cathode surface.

The current, in its passage through the solution, decomposes the nitrate of silver. Silver is deposited on the cathodes in the shape of dazzling white, coarse crystals, and nitric acid is formed. This acid attacks the anode, dissolving silver and thus restoring nitrate of silver to the solution. The nitric acid also dissolves the copper and some of the lead, and oxidises the bismuth and the rest of the lead, making products which remain undissolved in the bags.

I have mentioned that the density of the current is 18 ampères per square foot of cathode surface. This is high compared with the density used in copper refining, and is the cause of the loose crystalline deposit, as, with a low current density, the deposit tends to become cohesive. In the case of silver, this crystalline structure is of advantage, as the silver can easily be brushed off and collected at frequent intervals. If it were deposited in a cohesive coating, either a far greater quantity of silver would need to be carried in stock, which would unduly increase the interest charges; or, one would have to be continually remelting old cathodes and making new ones, which would be expensive.

A current of 1 ampère will deposit from a solution of silver nitrate 1·12 milligrams of silver per second; a current of 180 ampères, therefore, will deposit 201·6 milligrams per second. According to the second of Faraday's laws, the same current will deposit equal amounts, simultaneously, in each of the seventy baths; consequently, our current should deposit 14·11 grams per second in the whole series. This amounts to a deposition of 50·8 kilograms per hour, or 1219·28 kilograms per day (=39,205 troy ounces). As the horse-power expended to deposit 50·8 kilograms per hour is about 22, it follows that each kilogram of silver deposited consumes about $\frac{2}{5}$ horse-power per hour ($\frac{1}{5}$ pound per horse-power per hour). Although, theoretically, our 70 baths should deposit 39,205 ounces per day, in practice this yield is not obtained for several reasons:

(1) The anodes have to be drawn up out of the baths, for the purpose of cleaning up the gold and silver. This consumes considerable time each day.

(2) Shorter interruptions of the deposition are necessary for replacing anodes, cleaning connections, examining insulations, etc.

(3) With our small machine, which is not quite large enough for the work put upon it, constant vigilance is necessary to keep the current up to 180 ampères throughout the 24 hours, and, of course, any lowering of the intensity of the current means a proportionate decrease in the output.

The actual working results, day in and day out, will average 33,000 ounces per day for the seventy baths. We could, for a short time, deposit in the whole plant 45,000–50,000 ounces per day; but in the long run it will be found necessary to keep about one-seventh of the tanks under repair all the time.

The labor required in the process is slight. A carpenter is employed constantly in repairing and rebuilding tanks, making brushes, boxes, etc. A mason and a machinist are needed about one day each per week for other repairs. Three men on day turn and one at night are all that are required to do the regular work, which consists of cleaning up and melting the fine silver, preparing the anodes and placing them in the bath at the proper time, cleaning up and refining the gold slimes, melting scrap silver, keeping connections clean and insulations perfect. Each tank is cleaned of silver every other day, and of gold once a week. A full-sized anode is dissolved in about two and one-half days.

The deposited silver, as soon as it is taken from the tanks, is washed thoroughly with hot water, in order to rinse out the copper-bearing solution. It is then melted down in a large plumbago retort, which is capable of holding 18,000 ounces (or 1,200 pounds avoirdupois). The fuel used is natural gas. Each retort melts on the average about 5 tons before breaking.

The fineness of the silver produced is 999—often 999½. Indeed, it would require no effort to produce silver 999½ fine regularly, if it were of any advantage. By repeated washing it is possible to obtain almost absolutely pure silver. We

have furnished it to the mint as fine as 999·85. The gold slimes are melted, granulated and parted by acid. The resulting gold is 996–998 fine.

The electrolyte (of which I show a sample) is of a beautiful green color, due to the presence of 4 per cent. or 5 per cent. of copper. It also contains a small percentage of lead. As has previously been stated, when these three metals are present in nitric solution, the silver (being the most electro-negative) is deposited before the others. So long as the copper and lead are not present in too large quantities, and so long as a proper amount of acid is used, the silver will be deposited in a state of absolute purity. As the copper and lead accumulate to a dangerous degree, it becomes necessary to withdraw part of the solution, and, after throwing out the silver with salt, to precipitate the copper and lead.

With large percentages of copper in the anodes, we have not been able to obtain silver fine enough to ship to the mint. Mr. Moebius, in his Mexican plants, has, I believe, treated bullion carrying 30 per cent. to 40 per cent. copper. But it is to be noted that the Mexican mint is not as strict as our own, and is satisfied to take silver containing 10 per cent. copper.

In 1891, the production of electrolytic silver in the United States was about 8,000,000 ounces, or about 13 per cent. of the total production. The production of 1892 will exceed this somewhat, owing to the adoption of the process at St. Louis, and to increased output of the Pennsylvania Lead Company. It will exceed 10,000,000 ounces.

Copper.—Shortly after Elkington obtained a patent for his process for the electrolytic refining of copper in 1866, copper refiners in various parts of the world began to adopt it, especially in England and Germany. In these countries there are plants that have been in operation more than a score of years. At the present time, the copper production of Germany at least is almost entirely refined by the electrolytic process. More recently modifications of this process have been very generally introduced into this country,

until now practically all the refining of argentiferous copper is done by electricity.

In 1890, the estimated production of electrolytic copper in the United States amounted to 24,000,000 pounds, or about one-eleventh of the entire production of the country. In 1891 the amount increased to 36,000,000 pounds, or about one-eighth of the total product.

In 1892 it is estimated that at least 50,000,000 pounds, probably one-sixth of the entire output of the United States, will be deposited by electricity.

In the near future the immense output of the Anaconda mills (heretofore sent across the water) will be treated in this country, and still further increase the percentage of electrolytic copper.

The process is now in operation in fifteen to twenty refineries in the United States. The largest of these are:

The Baltimore Copper Smelting and Rolling Company, Baltimore, Md.; Balbach Smelting and Refining Company, Newark, N. J.; Boston and Montana Copper and Silver Mining Company, Great Falls, Mont.; Bridgeport Copper Company, Bridgeport, Conn.; Anaconda Mining Company, Anaconda, Mont.; Baltimore Refining Company, Baltimore, Md.; Chicago Copper Refining Company, Blue Island, Ill.; Lewisohn Bros., Pawtucket, R. I.

The total estimated capacity of all the electrolytic plants aggregates 4,000 tons per month, that is, these works running full could refine about twice as much as the estimated electrolytic production of the present year.

The general principles involved in this process are the same as those upon which silver deposition depends. The electrolyte in this case is a solution of sulphate of copper. Plates of impure copper (95 per cent. to 98 per cent.) form the soluble anodes, while the cathodes are thin sheets of pure copper. In two important modifications, called Smith's and Hayden's processes, the plate of blister copper answers as both anode and cathode. In Smith's process the plates are arranged horizontally, and the current causes the solution of copper from the under side of each plate, and a corresponding deposit on the upper side of the

plate below. This upper surface receives a coating of wax, or paraffine, which prevents the deposit from cohering firmly to the impure copper. Cotton screens are placed between the plates to catch the undissolved metals. Hayden's process differs from Smith's in having the plates suspended vertically, as in the Moebius process, and in having no screens between the plates.

The copper, on account of the low density of the current, is deposited in a coherent layer in the form of a skin—not in loose crystals. In some of those plants in which pure copper is used as cathodes, these "skins" are peeled off as soon as they are thick enough to bear their own weight, and are used as cathodes. When the copper deposit has reached a certain thickness, the cathodes are removed from the bath and melted for shipment. The impurities (lead, silver, gold, arsenic and antimony) remain undissolved, drop to the bottom and are regularly cleaned up and refined. Iron and nickel go into solution, but are not deposited, being electro-positive compared with copper. The arrangement of the baths varies in different establishments. In some they are arranged entirely in series, *i. e.*, the whole current traverses each bath; in others, the current from the dynamo is divided into several parts, each traversing a set of baths arranged in series.

A striking difference between a silver electrolytic plant and one for copper, lies in the size of the electrodes and the number in each bath, as well as the number of baths. The anodes may be 36 inches long by 24 inches wide and 1 inch thick, weighing over 300 pounds each. The number of anodes in each bath varies from 16 to 18 up to 100. The number of baths in the larger works is from 200 to upwards of 400. Thus, an enormous quantity of metal is held in stock, compared with amount required in the Moebius process. By thus increasing the size of the electrodes, and the number in each bath, the resistance is proportionally decreased, causing a smaller expenditure of power for the same amount of copper deposited. The interest charges are of course increased. Each plant must decide for itself how far it can afford to decrease

the consumption of power by increasing the quantity of metal carried in stock. Some of the large anodes require two months to dissolve, while the cathodes are left undisturbed between two and three weeks.

In order to deposit copper in large quantities daily, as is necessary in these days of fierce competition, currents of great intensity are used. On account of the low resistance, the E.M.F. required is low also. Some of the machines in use generate a current of 3,000 ampères, which means a deposition of about 8 pounds per hour for each bath in a series. The greater number, however, use a current of 1,000–2,000 ampères. The E.M.F. varies from 6–100 volts, one or two machines going as high as 150. The anodes in this process are produced by a series of treatments of ores and mattes by fire. A large part of the cost of producing copper lies in this preliminary treatment.

Lately, two processes have come into use in Germany, which do away with fire, and which appear to be successful in obtaining an electrolyte directly from the ore in the wet way. The two processes are similar in principle, differing only in solvents used and in minor details. It is claimed that by these processes, low-grade copper ores which have never repaid treatment can now be treated at a profit.

In the Siemens process, the pulverized ore, or matte, is leached with a solution of neutral ferric sulphate, which has the property of converting cupric and cuprous sulphide, as well as metallic copper, into cupric sulphate, which is dissolved. In the operation, the ferric sulphate is changed to ferrous sulphate. This solution of ferrous sulphate and sulphate of copper is conducted to the electrolytic tanks, where it serves as electrolyte. At this point a small amount of sulphuric acid is added. The anodes are carbon, consequently insoluble. The solution from the leaching vats is fed continuously into the cathode chamber, where the copper is deposited. Thence it passes to the anode chamber where the oxygen set free by electrolysis converts the ferrous sulphate into basic ferric sulphate. It is thus that the polarisation, which is generally excessive where insoluble anodes are used, is overcome. The free sulphuric acid in the solu-

tion converts the basic ferric sulphate into neutral ferric sulphate, and the process of regeneration is complete. The solution, as it leaves the electrolytic tanks, is pumped up and used for leaching a fresh portion of ore.

In Hoepfner's process, the solvent is a solution of cupric chloride in strong brine, or in a concentrated solution of chloride of lime. This solution will dissolve the sulphide of copper and silver, with precipitation of sulphur and conversion of the copper salts into cuprous chloride. From cuprous chloride solution, nearly twice as much copper is deposited by a given current as from a solution of the sulphate. As in the other process, this solution is fed continuously into the cathode chamber, where the copper is completely precipitated. An equal amount of this same solution is fed simultaneously into the anode chamber, where the liberated chlorine converts cuprous chloride into cupric chloride. The solutions coming from both chambers are mixed together, thus regenerating the original solution.

It is stated that Siemens' process is in use in only one plant near Berlin, but that Hoepfner's process has been adopted at three places in Germany. It is quite likely that this process may soon come into prominence and mark another decided advance in the metallurgy of copper.*

Aluminum.—In no department of metallurgy has electricity achieved so great a success as in the production of aluminum. It has fairly monopolised the whole field, and driven the old chemical processes out of existence. Indeed, before the advent of electrical methods, aluminum was so

* From vol. iii, of Rothwell's "Mineral Industry:"—The production of electrolytic copper in the United States, in 1894, is given as 115,000,000 pounds. The old-established refineries, such as those of the Balbach Smelting and Refining Company, the Baltimore Electrolytic Company, and the Bridgeport Copper Company, increased their output, and several new works have been started or enlarged. Among the latter may be mentioned the works of the Nichols Chemical Company, at New York; the Boston and Montana Company, at Great Falls; and the electrolytic works of the Anaconda Company, at Anaconda, which were remodeled in 1894 on the Thofehrn plan; the works building at Salt Lake City, embracing a Bessemer and an electrolytic plant; and the large works of the Guggenheim Brothers, under construction near Perth Amboy, N. J. W.

expensive as to preclude its use in the arts, and the whole development of the aluminum industry may truthfully be credited to electricity. In 1855, when it was first produced in quantity, it was valued at $90 per pound. As methods were improved, the price gradually fell to $5, in 1887. In 1888, the Pittsburgh Reduction Company began to produce pure aluminum by electricity, and placed it on the market at $2 per pound. At present, the metal is quoted at 50 to 65 cents per pound, according to purity. The total world production, from 1860 to 1889, inclusive, is estimated, by Mr. R. L. Packard, at 232,000 pounds. During 1890 and 1891 alone, the production in the United States amounted to 258,000 pounds. These figures show what a revolution has been wrought by electricity in this field.

It is not my intention to enter into a detailed description of the processes in use, but I will simply mention some of the points wherein they differ from the processes already described.

The one great difference is the condition of the electrolyte. Hitherto we have spoken only of solutions. The electrolyte in the aluminum bath is in a state of fusion. It consists of a solution of alumina (artificially prepared from the ore) in molten cryolite, which is a double fluoride of aluminum and sodium. The electrodes are of carbon, and the passage of the current through the electrolyte generates sufficient heat to keep it melted. An enormous quantity of power is absorbed in this process, amounting, according to Mr. Hunt, the president of the company, to 22 horse-power per pound per hour.

The principal producers of aluminum and alloys in the world are: The Cowles Syndicate Company, England; The Metal Reduction Syndicate, England; The Alum. Industrié Actien Gesellschaft, Switzerland; The Cowles Electric Smelting and Aluminum Company, Lockport, N. Y., and The Pittsburgh Reduction Company, Pittsburgh, Pa.*

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* Since the delivery of this lecture there have been no radical changes in the metallurgy of aluminum. The electrolytic method of production still maintains its supremacy, and the entire product is thus manufactured. The Pittsburgh Reduction Company is at present the sole producer of the pure metal in the United States. This company has just put in operation an

Lead.—Mr. N. S. Keith has patented a process for refining lead bullion, in which the method of treatment is very similar to that used in copper refining. The anodes are plates of impure lead, the electrolyte is a solution of sulphate of lead in acetate of soda. The process was entirely successful, mechanically and metallurgically, but the cost of treatment was too great, and the large works erected in New York were abandoned. It is probable this process will again be heard from in the days of cheap electricity.

Considerable interest has been manifested in electrolytic processes for recovering zinc from its ores, but nothing of value has yet been attained in that direction. Zinc is so cheaply produced by fire, the energy necessary for its electrolysis is so great, that it does not seem likely that these attempts will be financially successful in the near future.

To summarise: we have found that, within the last two decades, electricity has entered the metallurgical arena, and has achieved for itself the refining of one-sixth of the copper and silver produced in the United States (not to mention the Old World) and the production of the world's entire output of aluminum.

The processes thus far mentioned constitute about all the electro-metallurgical processes in general use at the present time. Numerous patents have been granted on processes for electrolytic treatment of various kinds of ores and for refining metals, but as yet they have met with no great success. As electricity becomes cheaper, however, there is every reason to believe it will play an increasingly important part in the metallurgical arts.

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extensive electric plant for the metal at Niagara Falls. These works will be able to utilise 5,000 horse-power.

In Europe, the Aluminium Industrie Gesellschaft, at Neuhausen (Switzerland), continues to be the largest producer. Dr. J. W. Richards estimates the world's production of the metal, in 1894, at 2,246,000 pounds, valued at $1,123,000. Of this amount there were produced in the United States 706,000 pounds, or about 30 per cent. The production of 1894 was nearly double that of 1893. The selling price of the metal in the United States was from 50 to 63 cents per pound, according to size of order and quality. Taking into consideration the large increase in the capacity of European and American works, lately made or in course of extension, the same authority believes that the production of aluminum in 1895 will be in the neighborhood of 8,000,000 pounds, or 4,000 net tons. W.

NOTES AND COMMENTS.†

SELF-PROPELLING VEHICLES.

The following editorial expressions, which we reprint from a recent impression of the *Electrical Engineer*, besides giving a very sensible summary of this interesting subject, contain one highly suggestive reference to the possible utilisation of the trolley system in connection with the development of this species of road travel, which may be as new to our readers as to ourselves, viz.:

"There is, perhaps, no country in the world where art, science and industry are so much encouraged by the awarding of prizes for meritorious work and progress as in France; and although it might possibly be argued that no invention or appliance of the first order of importance was ever the direct outcome of a prize competition, still it is not to be denied that the origin of many advances can be traced to the stimulus of a prize competition. Even if such competitions do not always result directly in bringing out the desired improvement, they nevertheless draw attention prominently to the object in view, and set to work many who would otherwise remain passive, if not in total ignorance of the needs of the times. We are led to these reflections in contemplating the results of the late self-propelled vehicle competition over the road between Paris and Bordeaux and return, which has attracted more than an ordinary amount of attention, and deservedly, as it touches so closely the question of cheap and rapid transportation. To look upon the results of this competition merely in the light of a race organised by wealthy amateurs with a fad, is to ignore the philosophy of the history of transportation, and more particularly the most recent part of that history, as embodied in the annals of the electric railway for the last ten years.

"The horse has already been practically banished from the streets of American cities as a popular means of passenger transportation, and gradually, but surely, the rest of the world will follow American example. But the highway and country road still afford an asylum to the horse; yet even here, as the recent contest in France has shown, he is not safe from competition.

"The result of the race demonstrated the remarkable qualities of the petroleum motor over a course covering such a distance, and must have been a disappointment to those who had cherished hopes for the success of the electric carriage which entered the lists. The result, so far as the electric carriage was concerned, might have been foreseen. We have never been accused of lukewarmness in advocating the adoption and application of electricity to any useful purpose suggested, but a consideration of all points involved leads us to the unavoidable conclusion that, for *long distances, such as those covered in the Paris-Bordeaux contest*, the electric storage battery carriage is not yet available. * * * It requires 250 pounds of battery and

† From the Secretary's monthly reports.

motor to produce one horse-power hour, and, handicapped in this fashion, it is useless to pretend that the storage battery can compete with power directly applied, by a prime mover weighing less than one-quarter of the necessary electrical equipment. Granted even that a lighter form of storage battery may make it possible to reduce the weight, even the copper-alkaline cells would hardly reduce the weight of battery more than one-third. We have, in the above comparison, considered the electric storage battery carriage in the light merely of a long-distance traveler; but while compelled to admit its inferiority under such conditions, we are by no means ready to concede like superiority for the petroleum motor for the ordinary distances, to cover which wagons are usually employed. After all, the French contest was a *tour de force*, and it is doubtful if any one, desirous of going from Paris to Bordeaux and return, on business, would dream of selecting the wagon-road instead of the steam railway. To that extent, therefore, it is necessary to modify the opinion which one is apt to form at the start. * * *

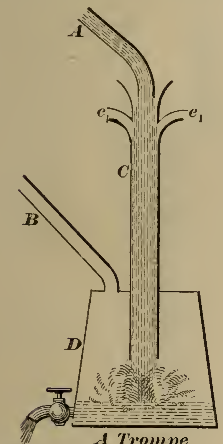
"The first consideration in modern travel is comfort, and this holds true as well for short as for long distances. It is this requisite, aside from the question of speed, which has made the stage-coach and omnibus a memory in most civilized countries, and has given the electric car the popularity it enjoys. Granted, then, the conditions of short haul (which is the normal work of a road carriage) and maximum comfort, we are not alarmed for the future of the electric carriage. On the contrary, comfort being the first consideration in vehicles of this type, the comparison, as between a heat engine of any description whatever, and the electric motor, becomes almost ludicrous. Far, therefore, from losing courage, those who are devoting their attention to the construction of electric carriages should redouble their efforts. The several recent designs of electric carriages actually constructed * * * give evidence of intelligent thought, and, with the improvements suggested by their operation in practice, we may soon expect the creation of a regular demand for such vehicles. Nor must it be forgotten that there are other means of electric propulsion to which ordinary road vehicles are well adapted, and that the trolley carriage, fed by current from overhead conductors, is by no means as remote as it would appear to be. Requiring no outlay whatever for track construction and repairs, rights of way, etc., a system of electric trolley carriages might in many instances be found profitable where a railroad would not pay. It may appear as a begging of the question to put forward the trolley carriage in a discussion of self-propelling vehicles, but we mention it merely to show that the methods at disposal for electrically-driven vehicles are by no means confined to the storage battery, while, naturally, the energy supply of all other types of carriages is limited to their fuel-carrying capacity.

"All indications point to a rapidly growing interest in vehicles of this class, an interest which is stimulated by the announcement of two new competitions—that organized by the *Times-Herald*, of Chicago, with $5,000 in prizes, and the other, by the London *Engineer*, which holds forth incentives in the shape of prizes aggregating 1,000 guineas. These competitions will enable American and English inventors to test their vehicles of this class, and will afford a useful means of comparison with those of French design."

DURFEE'S HYDRAULIC VACUUM PUMP AND BLOWPIPE.

Mr. W. F. Durfee, whose familiarity with the historical evolution of the mechanical arts is widely known to the readers of current engineering literature, in a recent impression of the *American Machinist*, gives a description of "that very ancient mechanism for 'raising the wind,' called a *trompe*," in connection with certain modified forms of compression and vacuum apparatus, based on the same general principle, which he devised in 1869. Of this article the following abstract may be of general interest. The *Journal* is indebted to the *American Machinist* for the use of the cuts.

Fig. 0 is a vertical section of one form of the trompe. The water which operates it discharges from supply pipe *A*, into the flared top of the vertical pipe *C*, which is furnished near its top with several inclined apertures e e_1, for the admission of air. In descending *C*, the water draws in air through these apertures, carrying it downwards into the closed chamber *D*, where the water



A Trompe
American Machinist
Fig. 0

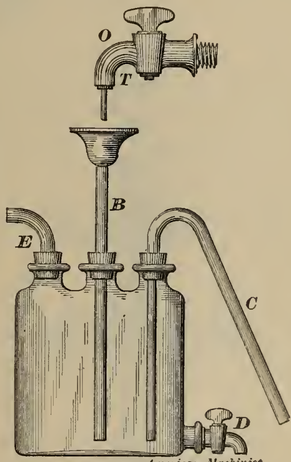


Fig. 5 American Machinist

dashes upon some obstruction, and is converted into spray, from which the entangled air separates, and, collecting in the upper part of the chamber *D*, is conveyed where desired through the pipe *B*, while the water collects below and is discharged through a cock or other outlet provided for the purpose.

The author places the trompe among the earliest mechanisms for furnishing air to furnaces and forge fires. It is believed to antedate the Christian era. Pliny speaks of it (A. D. 76), and Branca (1629) and Kircher (*Mundus Subterraneus*, 1665) give illustrations of the apparatus as applied to the blowing of organs and forge fires. In 1867, Bunsen applied the principle in the construction of his well-known filter pump. Mr. Durfee, in 1869, designed what he believes to have been the first apparatus in which the two functions of the trompe—compression and vacuum—were combined.

Mr. Durfee's combined vacuum pump and table blowpipe will be understood from the following description with the aid of the cuts:

Fig. 1 is a general elevation, with air chamber sectional; *Fig. 2*, a plan of the air chamber; *Fig. 3*, a vertical section of the vacuum pump on line *C D*, of *Fig. 4*, which is a horizontal section on line *A B* of *Fig. 3*.

The vacuum pump is constructed of copper. The vacuum chamber *E* is

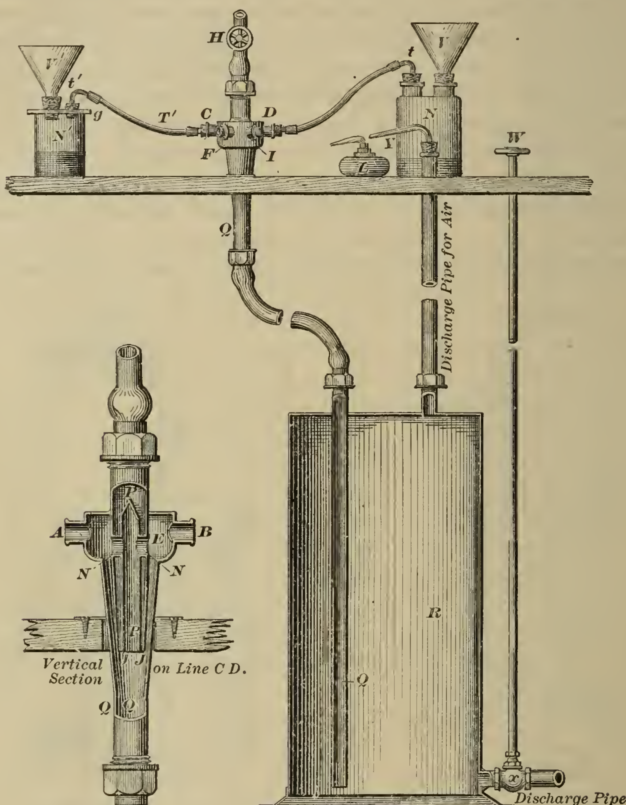
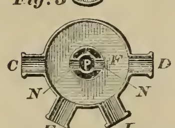
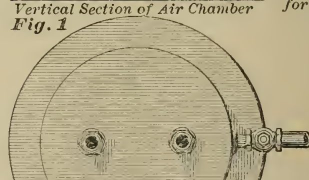


Fig. 3

Vertical Section of Air Chamber
Fig. 1



Section on Line A B
Fig. 4


Plan of Air Chamber
Fig. 2

American Machinist

supported on the upper expanded end of pipe *Q*, and has four nozzles (*C*, *F*, *I*, *D*), *Fig. 4*, two of which are seen in section at *A B*, *Fig. 3*. *P* is the water supply pipe, at the lower end of which is an internal pipe *p*, communicating with the vacuum chamber, and supported by two elliptical nozzles *N N*. The upper end of pipe *P* is closed by a conical cap. The relative sizes of the

pipes *P* and *p* are such that an annular adjutage, one-sixteenth of an inch in thickness, is formed between their lower ends, through which the water from the supply pipe *P*, passes into pipe *Q*, drawing along with it any air that may be in the vacuum chamber *E* and upper conical part of pipe *Q*, the air in *E* having free access to the interior of the hollow cylindrical jet through the nozzles *N N* and the internal pipe *p*.

When the apparatus is to be used as a filter pump, one of the nozzles, *C*, *F*, *I*, *D*, is connected with the vessel to receive the filtrate, or several or all of them may be so connected and operated simultaneously. The several modes of making such connections and the construction of this air chamber are so clearly shown in the cut as to make more detailed description unnecessary, and it is scarcely necessary to notice that the orifices of the unused nozzles must be properly closed by stoppers when the pump is in operation, and the valve *x* in the discharge pipe for water kept open. The action of the pump may be controlled according to requirement by the valve *H*, *Fig. 1*, which regulates the water supply.

When the apparatus, *Fig. 1*, is to be used as an air compressor and blowpipe, the stoppers are removed from *C*, *F*, *I*, *D* to allow the air free access to the vacuum chamber, the valve *x* in the discharge pipe for water is partially closed, and any desired form of blowpipe inserted in the upper end of the air discharge pipe, as shown at *Y*, *Fig. 1*. If the blast is required at some distance from the apparatus, a rubber tube of convenient length will be used for the purpose, and to the end of this the blast tuyere, held in some support, will be attached. The *modus operandi* of the air compressor will need no description. It should be observed, however, that, to obtain the best results, the air chamber *R* should be located about 10 or 12 feet below the point of discharge of the blast. The volume and pressure of the blast may be regulated within the maximum limits by the suitable adjustment, respectively, of valves *H* and *x*.

Fig. 5 represents a form of trompe blowpipe made by Mr. Durfee, in 1863, for use in the laboratory of the steel works at Wyandotte, Mich., and has the advantage of being readily arranged with the means usually at hand in every laboratory. It is formed of a three-necked flask, fitted air-tight with the funnel tube *B* extending nearly to the bottom, with a siphon tube *C* (for which, when a two-necked flask is used, a cock *D* may serve) and with an outlet pipe *E*, for conveying the blast where it may be required for use. In service, this apparatus is placed beneath the hydrant cock *O*.

ELECTRICALLY-LIGHTED BUOYS IN THE GEDNEY CHANNEL, NEW YORK HARBOR.

London *Nature* has the following to say respecting the successful lighting of the Gedney Channel entrance to New York Harbor:

"A remarkable system of electric lights on buoys has just been completed at the Gedney Channel, off Sandy Hook. This channel is only 1,000 feet wide, and vessels have not, heretofore, been able to pass through it by night. The new system, however, provides a brilliant thoroughfare, lighted by ten

incandescent lights of 100 candle-power each, and each on a buoy, about fifty feet long, and rising twelve feet out of water. The cable which conveys the electricity carries the pressure of 1,000 volts under water, and is six and one-half miles long, being the longest cable in the world carrying a high-pressure current under water, and also the only one of its kind ever made. It consists of a copper conductor, insulated with gutta-percha, bedded in jute and sheathed with hard-drawn copper wire. The machines have an output of only 100 volts, but the current flows through a step-up converter, back of the switchboard, where it is converted into the required voltage, being thus perfectly safe to operate."

THE PHYSICAL PROPERTIES OF ARGON.

Lord Rayleigh, in a recent communication to London *Nature*, contributes the following data bearing on the chemical position of argon. The gas was prepared from atmospheric air with the aid of oxygen and alkali only:

"Weighings at 0° C. upon a large scale (two liters), and with the apparatus formerly employed for other gases, give, as the density of argon, ($O_2 = 16$)

$$19{\cdot}940,$$

a number in almost exact agreement with that obtained by Professor Ramsay, working upon a relatively small scale, and with gas derived by magnesium (Rayleigh and Ramsay, *Phil. Trans.*, 1895).

"In spite of its greater density, the refraction ($\mu - 1$) of argon is only ·961 of that of air; so that if we take for air under standard conditions

$$\mu = 1{\cdot}0002923,$$

then for argon

$$\mu = 1{\cdot}000281."$$

PRIZE FOR ELECTRIC HEATERS.

It may interest American inventors to know that the German Hygienic Association offers a prize of $1,200 for a research essay on the efficiency of electric heaters. The programme is as follows: "The heat given out in heating installations by heaters in their various forms and modes of use is to be ascertained. The investigations are to be described in detail in respect to the arrangement of the heaters, the nature of the heating agents and the observations made; and they are to be illustrated by drawings. The heating values obtained are to be stated in units of heat given off per hour per unit of surface. In the case of heat given out to air, the investigations must be conducted with currents of air at speeds as different as possible. The heaters are to be described in detail as regards form and measurement, and the relation of their heating efficiency to their weight is also to be ascertained." Essays are to be written in German, and sent with a motto and sealed envelope to Prof. Konrad Hartmann, Charlottenburg, Fasannstrasse, 18, before July 1, 1896. The essay will remain the property of the successful competitor, but he is required to publish it within six months, and to give the prize offerers gratuitously 300 copies. The offerers reserve the right to divide or withhold the prize.

METALLIC SODIUM FROM LEAKAGE CURRENTS.

The curious observation, lately made in England, of the formation of metallic sodium as the result of the electrolytic action of leakage currents, has been duplicated by a similar observation recently made in Boston. The case in question formed the subject of a report by Messrs. Forbes & Glidden to the Boston Fire Underwriters' Union, and related to the examination of a substance found in the casing about the electric mains in the basement of the Pray building. The following abstract from the report is taken from *The Electrical World:*

"The substance discovered was in reality impure metallic sodium mixed with partially disintegrated wood, the metallic sodium being the product of an electrolytic decomposition of impure sodium hydrate. This sodium hydrate came from the cement mortar used in laying the brick wall of the basement, upon which the wires were supported. Some of the hydrate may have possibly worked its way through the wall from the cement used in the foundation of the paved street (Washington Street) immediately adjacent.

"The electric current which caused the electrolytic action was due to a leak inside the casing from one of the mains to another, the leak having been produced by the action of the sodium hydrate on the insulating covering of the wires. This covering was what is known as 'weather-proof,' consisting of a cotton braiding covered with tar, which material is readily attacked by sodium hydrate and its insulating properties destroyed. * * *

"Inside the casing the wires were partially covered by an insulating tubing consisting of tarred paper. * * *

"The wood at this point (*i. e.*, where the sodium was found. W.), was badly eaten and discolored by the caustic action of the sodium, and for some distance around, especially along the top of the casing, was soft and wet.

"For several months before the sodium was found, a slight smoke had been noticed to issue occasionally from the casing. When the front of the casing was removed, the wires, tubing and woodwork about this point were covered with a thick liquid, which had dried in places to a white substance resembling discolored salt and which was slippery to the touch and strongly corrosive. The metallic sodium was smoking, and, when moistened and struck with any hard material, gave off flashes of fire.

"The following tests were made shortly after the discovery of the deposit, upon which the explanation given above is based. The substance was determined to be mainly metallic sodium by its appearance and characteristic reactions, and by its color in the Bunsen flame. The sample upon which the test was made was about half wood partially disintegrated, adhering to which was a mass composed of white sodium hydrate on the outside, with the metallic sodium in the centre.

"Samples were taken from the surface of the wall at numerous points along the front of the basement, each of which gave a strong alkaline reaction. The moisture on the wall was also strongly alkaline.

"The insulation on the wires about the point where the sodium occurred was found to be practically destroyed. The upper two wires (negative) were

in the worst condition, the middle two (neutral) were nearly as bad, while the lower two (positive) had not been so much affected.

"The outer covering of tar, especially on the negative and neutral wires, had been dissolved by the action of the caustic, leaving the braiding bare and saturated with the sodium hydrate, which had dried white in places."

BOOK NOTICES.

Illustrated Catalogue and General Description of Improved Machine Tools for Working Metal. Designed and constructed by William Sellers & Co., Inc., Philadelphia, Pa., U.S.A. Philadelphia: Printed by J. B. Lippincott Company. 1895.

The publication above-named has been issued in place of a new edition of the well-known "Treatise on Machine Tools" of this Company. This was found to be impracticable, by reason of the numerous changes that have been made in the forms and details of its standard tools, and of the number of new and important special tools that have been added to the list of the company's productions.

It was decided, therefore, to begin *de novo*, and to illustrate the new publication in the best style of the modern art of half-tone engraving, which presents the double advantage of an attractive appearance, and of giving a faithful delineation of each machine.

The present book, substantially bound in boards, forming a volume 7½ x 7½ inches, superbly illustrated, and a model of typographic execution, is the result.

Coming now to the contents, a few pages are devoted to a description of the works, (which, without detracting from the interest of the catalogue, might have been made more elaborate), and the remaining 400 odd pages are given up to the various products of the establishment.

The arrangement of the text and the form and size of the book appear to have been decided upon after careful consideration of the objects to be subserved. The various products of the company are arranged in classes. The left-hand pages give a description of the general features of the tools illustrated in each class; while those on the right contain the photo-engraved pictures of the "standard" or "special" tools, with title and brief specifications, giving principal dimensions, salient operative features, etc. The purpose of this arrangement is explained in the introduction to be "to present to our customers a book which shall combine the advantages of an illustrated catalogue of tools, with brief specifications for quick reference, together with a general discourse for more leisurely examination. A further object in determining the size and shape of the book has been to assist the convenience of the reader; the aim being to show all the tools, whether upright or horizontal, in the same position on the page and to avoid unwieldy size, while at the same time presenting illustrations of sufficient dimensions to exhibit details

clearly." The form and arrangement of the catalogue are admirably adapted to realise these objects.

Following is a summary statement of the principal contents:

About a dozen pages are devoted to general introductory remarks, stating the purpose of the work and giving a somewhat meagre historical sketch of the establishment, with a few pictures of interiors of several of its departments. Then follow, in the order named, the bolt and nut screwing machines, vertical drill presses, rail drilling machines, universal drilling machines, radial drills, horizontal drilling and boring machines, and drills and boring machines for special purposes, such as locomotive cylinder boring and facing, vertical cylinder boring, pulley boring, car-wheel boring, etc. Then follow standard and special lathes, ranging from the mammoth machine for turning and boring 16-inch guns, down. Next come the well-known tool and drill grinders, milling machines, automatic gear-cutting and wheel-dividing machines, rotary planers, shaping machines, slotting machine planers, plate planing machines, punching and shearing machines, steam hammers, steam and hydraulic riveting machines, portable riveting machines, hydraulic accumulators, bending rolls, hydrostatic wheel presses, hoisting machines, electric cranes, swing cranes, car cranes, hydraulic cranes, traveling cranes. Under the latter head is given an illustrated description of the 150-ton electric traveling crane built for the Carnegie Steel Company, Limited. The following pages are devoted to railroad turn-tables, injectors and hydraulic testing machines (the last including the system of A. H. Emery, the designer of the Watertown Arsenal machine), shafting, embracing the various appliances for the mechanical transmission of power, and mechanical stokers.

A very full, analytical subject-index is given at the close. W.

A Discussion of the Prevailing Theories and Practices Relating to Sewage Disposal. By Wynkoop Kiersted, C.E., New York: John Wiley & Sons. 1894. (Price, $1.25.)

The author treats this important subject concisely and intelligently. After giving a summary of the theme in his introduction, he treats of sewage and sewerage; the vital process of purification, by which he means to indicate the natural process of purification by bacterial oxidation; then, in succession, the methods of sewage disposal by dilution, by irrigation, by intermittent filtration, and by chemical precipitation. A general discussion of the merits of the foregoing methods closes the volume, which is an excellent *résumé* of the whole subject in the light of the latest and best opinion.

W.

Antisepsis and Antiseptics. By Charles Milton Buchanan, M.D., etc. With an Introduction by Prof. Augustus C. Bernays. Newark, N. J.: The Terhune Company. 1895. (Price, $1.25).

This compendium has been prepared for the use of the physician, and seems to contain in concise form everything essential to give the medical

practitioner a clear and accurate account of the evolution of antiseptic medicine and surgery from its early origin to the present. The present state of the art is presented very fully, not only by the concise statement of the views of its most eminent living exponents, but also by the compilation of the rules of practice recommended and followed by the leading surgeons.

A particularly valuable portion of the work is the chapter on "Antiseptics and their Relative Value," in which is given a digest of the properties of all the antiseptic agents known and used to any extent in medicine. It impresses the reviewer as a work which would be found extremely useful in library of every physician. W.

The Ventilation of Mines. Designed for use in schools and colleges, and for the practical mining men in their study of the subject. By. J. T. Beard, C.E., E.M. New York: John Wiley & Sons. 1894. (Price, $2.50.)

So far as we are aware, this is the first attempt of an American author to present the data upon this important topic in such form as to be available for the needs of the student of mine engineering. The elaborate treatises of Fairley, Atkinson and others are at present the only sources of authoritative information on the subject, and these are not suited for the use of the student or the average mining engineer. The author develops his subject very systematically and thoroughly, and the book ought to serve a very useful purpose. A series of practical problems is given at the close of the book.

W.

Jahrbuch der Elektrochemie—Berichte über die Fortschritte des Jahres, 1894, bearbeitet von Dr. W. Nernst und Dr. W. Borchers. 1. Jahrgang. Halle a. S. Verlag von Wilhelm Knapp. 1895.

The great increase of activity that has been apparent within the past few years in the field of electro-chemistry, in its application to the arts and industries, affords ample evidence that the cultivation of this branch of applied science is attracting the attention of an ever-increasing body of investigators. Until lately this activity was confined largely to the metallurgical field, in which many notable advances have been achieved, as witness the electrolytic methods for the refining of crude copper, argentiferous lead, the production of aluminum, the thermo-electric methods of working metals and reducing refractory oxides, etc. More recently, the attention of investigators has been directed, with increasing interest, to the great possibilities which electrolytic methods open in the chemical arts and industries, and the past few years has witnessed astonishing developments in these directions. They have been applied and, in many cases, with highly successful results, to the disinfection of sewage, to the dyeing and bleaching of textile fabrics and fibers, to the tanning of skins, and to the production of a great number of chemical products, such as soda and bleach, the chlorates, etc. The field is only fairly opened as yet, and the next decade will doubtless witness a radical revolution in the

practice of many of the chemical industries, brought about by the introduction of electrical methods.

The progress in this branch of applied science has been so rapid that the need by students and investigators for reference literature has been sorely felt. It is being supplied, in part, by recently founded periodicals devoted to it, and the present "Yearbook" is the latest addition to the sources of information that are accessible. There has been and is a positive want for such a record, and the Yearbook of Nernst and Borchers promises to meet it admirably. It is systematically arranged, being divided into two parts—theoretical and applied, which in turn are intelligently sub-classified—and appears to be quite exhaustive. The student and technologist will find it a storehouse of facts of the highest value, and it should take its place as a standard reference work in its special field. Both editors are well-known authorities in their respective specialties.

The publisher has issued the book in excellent form. It is very well printed and illustrated. W.

Encyclopédie des Aide-Mémoire. Dirigée par M. Léauté, membre de l'Institut. Paris: Gauthier-Villars et fils et G. Masson. [Price, per volume (small 8vo.), paper, 2½ fcs. Cloth, 3 fcs.]

The following volumes of this encyclopædia have appeared since the last announcement in the *Journal*, viz.:

Witz, Ainé. Docteur ès Sciences, Professeur à la Faculté libre des Sciences de Lille. *Les Machines thérmiques.*

Laurent, H. Examinateur d'admission à l'École Polytechnique. *Théorie et pratique des Assurances sur la vie.*

Léauté, H. Membre de l'Institut, et Bérard, A. Ingénieur en chef des Poudres et Saltpêtres. *Transmissions par câbles mètalliques.*

The reader is referred to earlier notices of this valuable publication which have appeared in our book columns. W.

The Mineral Industry: Its Statistics, Technology and Trade in the United States and other Countries, to the End of 1894. Vol. iii. Edited by Richard P. Rothwell. New York and London: The Scientific Publishing Company. 1895. (Price, $5.)

The third volume of this statistical, technological and trade review of the mineral industries forms a stately work of some 750 pages. We have stated in our review of previous volumes the unique advantages offered by the energy and enterprise of its able editor, in affording the professional engineer and the business man interested in mines and minerals, so promptly after the close of the year, the most reliable and complete information accessible respecting the subjects of which it treats. We have nothing—in this country, at least—which remotely approaches it in timeliness and comprehensiveness.

It would only be possible to accomplish a task of such magnitude with the

co-operation of a large staff of capable experts, and this aid the editor has been most fortunate in commanding from the beginning of his publication.

In considering the merits of the present volume of this important work, we find nothing to cause us to qualify the warm acknowledgment of its great value as a reference book to professional and business men interested in the mineral industry, which we have bestowed upon the earlier volumes. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 18, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 18, 1895.

JOS. M. WILSON, President, in the chair.

Present, sixty-eight members and eight visitors.

Additions to membership since last meeting, fifteen.

The Secretary, under instruction, reported a vacancy in the Committee on Science and the Arts, caused by the resignation of Mr. Clarence B. Schultz. The vacancy was filled by the election of Mr. John Haug for the unexpired term.

Mr. Robert Grimshaw presented an oral communication on a "Test of American Steam Snow-plows on the Prussian Military Railway at Mahlow," also a communication describing the "Improvement in Rail-Joints for Railways," devised by Prof. Koepcke. (To appear in the *Journal.*)

Mr. W. N. Jennings exhibited on the screen, and gave some account of, a series of photographs taken by himself, of the recent total lunar eclipse, which was visible in this locality, and which occurred under conditions extremely favorable for observation.

The Secretary's report included, among other matters, more or less extended descriptive references to the substitution of the electric locomotive on short lines of railway and for tunnel haulage; to the extensive system of subways now being constructed for passenger traffic in the city of Boston; to the recent trials, in France, of automobile carriages, and prospective trials of such vehicles to take place in November between Chicago and Milwaukee.

Adjourned.

WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXL. NOVEMBER, 1895. NO. 5

TESTS OF CEMENT MORTAR MIXED WITH VARIOUS KINDS OF SAND.

BY A. S. COOPER, U. S. Assistant Engineer.

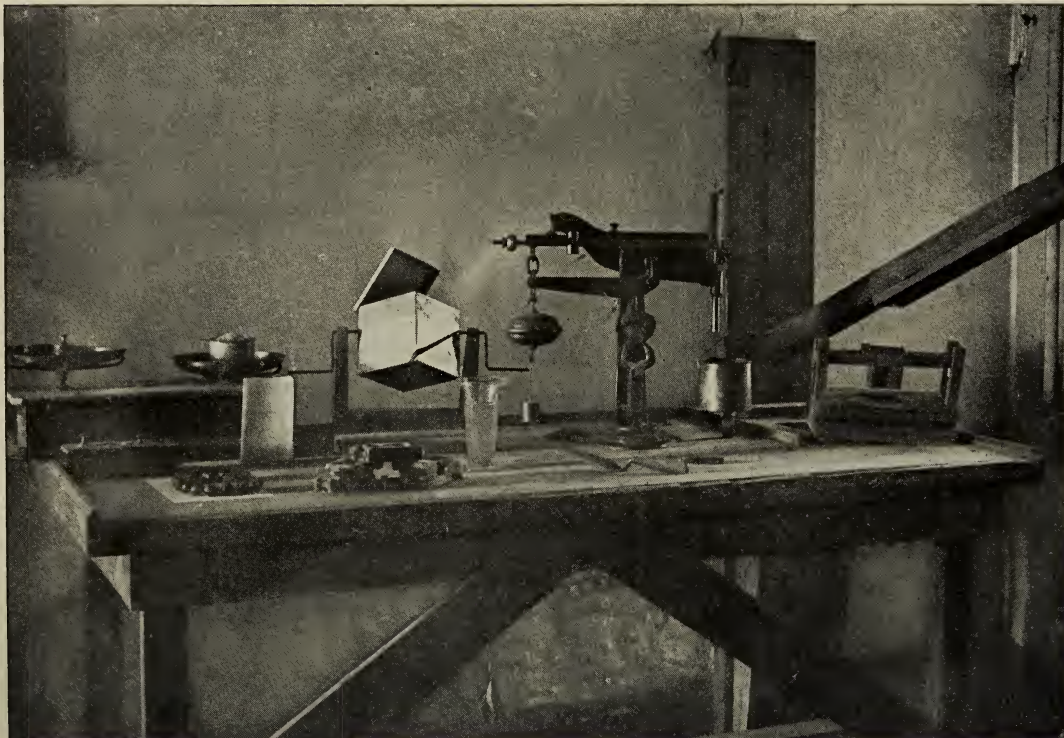
During the construction of a mining casemate at Fort Pulaski last year, the question arose as to the advisability of using fine beach sand instead of coarse river sand, on account of the greater cost of obtaining the latter. The writer took the position that the fine sand would be nearly as good, in fact good enough, and as its employment was estimated to save at least $1,000 in the total cost of the work. A short series of experiments was made, which, to the astonishment of all connected with the work, proved the fine sand to be slightly stronger than the coarse. These results were published in *Engineering News*, with some others on the effect of small percentages of mud and on the use of salt water instead of fresh. These results were mentioned by the editor as being opposed to those obtained by all previous experimenters, and this fact induced the author to

investigate the question in a more thorough and scientific manner.

The first matter to be settled was the method of working in order to eliminate as many uncertainties as possible. Where close figures are to be expected, a slight inaccuracy in the work might lead to erroneous conclusions. After looking over all of the different methods, the following were finally adopted as being the most suitable for this work:

Methods of Conducting the Work.—The sand was first graded by means of 13 sieves, ranging from 8 to 140 wires to the lineal inch, and the grades indicated by the 2 sieves used. The grade 8–12, for example, means that the sand in this grade passed a sieve with 8 wires to the inch, and was held by one with 12 wires. (See Table No. 2). It was concluded to mix the mortar rather dry, about the consistency of moist snow, so as to be able to handle the briquettes immediately after moulding them. It was also believed that a dry mortar would give more even results under uniform pressure than a wet one. The sand and cement were first carefully weighed, then they were mixed dry by means of a square box with a rod run through the corners, after the manner of Gen. Q. A. Gillmore's concrete mixer. The water was measured with a graduated glass, and mixed into the cement and sand on a stone table with a trowel. If the mortar appeared too dry, more water was added; and if too wet, note was made of the fact, and the set proceeded with. In nearly all cases enough mortar was made at one mixing to make 8 briquettes. Four of these were broken at the end of a week, and the remainder in 8 weeks. As a difference of 1 per cent. of water in the finished mortar, could not, in all cases, be detected, a series of tests was made (Table No. 6) to determine the effect of such variations. The results proved conclusively that slight variations in the amount of water might cause considerable differences. In drawing conclusions, therefore, the percentage of water used must be considered.

It should also be borne in mind that some cements and some sands of the same size, require more water than others to yield a mortar of the same consistency. Generally speak-



Scales, Mortar-Mixer, Testing-Machine, and Press. Tests of Cement Mortar Mixed with Various Kinds of Sands.

ing, fine sand requires more water than coarse, and natural cements more than Portlands. The briquettes were moulded in brass moulds of the form recommended by the committee of the American Society of Civil Engineers, in 1885, but were not pressed in by hand as recommended by this committee. The method used by Prof. Chas. D. Jameson was adopted. Prof. Jameson put his mortar into the moulds under a uniform pressure of 150 pounds per square inch, while in this work 200 pounds was used. The press consisted of a simple lever attached firmly to the wall by two long strap hinges, arranged at the proper height above a stone table. The brass mould was placed under this lever at a fixed distance from the hinge, and with a board on top of it having a hole cut in it the exact shape of a briquette. The mould and the hole in the board was then filled with loose mortar, and the lever applied to press the loose mortar into the mould. The piece that was cut out of this hole (with a scroll saw) was fastened to a square stick and arranged in such a manner that when the lever was applied nothing but vertical pressure would be transmitted to the briquette. Some trouble was experienced with sand getting between the socket in the board and the piece cut out of same, and it is believed that some inaccuracies have crept into the work, owing to the irregular pressure produced by the imperfect fit of these parts; but it could not be so great as the irregular and uncertain pressure applied by the hand, even of an experienced operator. The pressure was applied by putting a constant weight on the end of the lever. A set of tests was made (Table No. 7) with varying pressures obtained by a longer lever than the one used for the main work, to see what would be the effect of the different pressures. By this table it will be seen that, although the effect of an increase of pressure is quite marked, yet slight changes, sometimes even doubling the pressure, have very little effect. It is, therefore, probable that such slight changes as might be produced by irregular friction of the working parts of the machine used, would produce but little if any effect on the strength of individual briquettes in any one set. As soon as taken from the press, the briquettes were removed from the moulds, placed on a

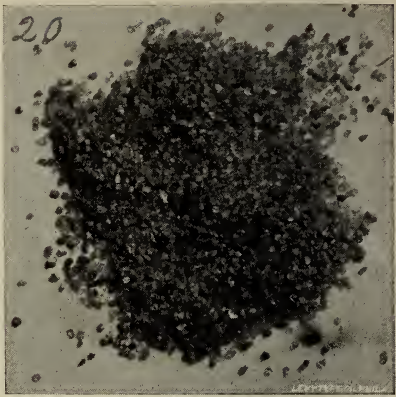
stone slab and covered with a wet cloth, where they remained for twenty-four hours, when they were immersed in water for the required time. The briquettes were identified by means of letters and numbers. Just before removing from the moulds, a figure was pressed into one head and a letter into the other with a rubber stamp. The letter indicated the cement used, the number being the number of the set made with that cement. The briquettes were broken with a Fairbanks machine of 1,000 pounds capacity, and the strain was applied at the rate of about 300 pounds per minute (see illustration opposite).

In order to compare the general accuracy of this work with that of other operators, the writer has constructed a table of results (Table No. 26) from three other sources, in all of which the methods recommended by the American Society of Civil Engineers were used. The first two investigators were students just from college, and could not have had any great amount of experience, especially as compared with Col. Poe. It will be seen that the results obtained by the writer are, at least, as accurate as those of Col. Poe, a circumstance which he attributes to the better methods he employed. In Table 26 the greatest difference of any one briquette from the mean of the set was used, and this difference divided by the mean strain of the set, to get the percentage of error. Where more than one set was given, the mean of all of these differences was divided by the mean of all of the strains. The greatest difference in any one set is also given, but the percentage is figured from the mean. No attempt was made to secure a uniform temperature, but in nearly all cases each series of tests was made on the same day, so that each set in each series was subjected to the same temperature.

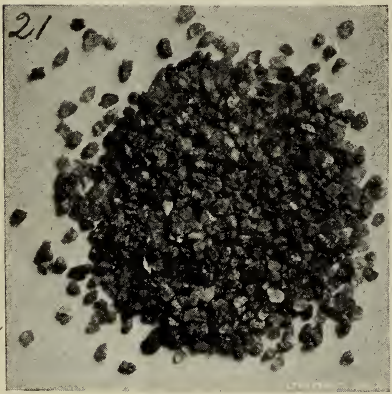
DESCRIPTION OF SANDS.

River Sands.—This sand was taken from the bed of the Savannah River. It is of light-yellow color, quite clear, and is composed of a mixture of sharp grains, and well-rounded ones. The coarse grades seem to have a greater percentage of rounded grains than the fine ones. (See Tables Nos. 11 and 12.)

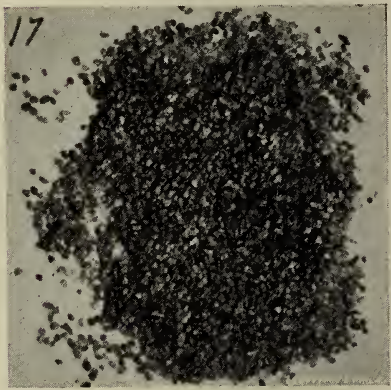
RIVER SAND.
Size, 70-80.



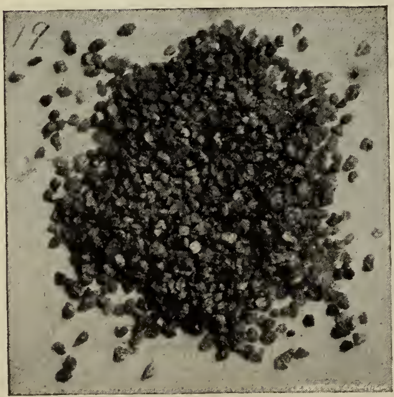
RIVER SAND.
Size, 20-30.



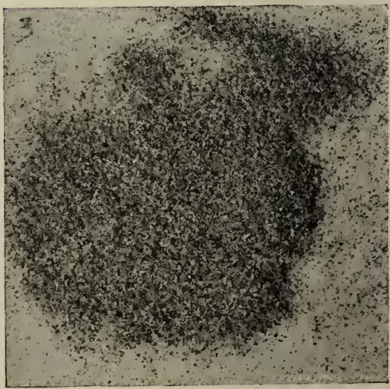
RIVER SAND.
Size, 12-16.



AUGUSTA, No. 1.
Size, 20-30.

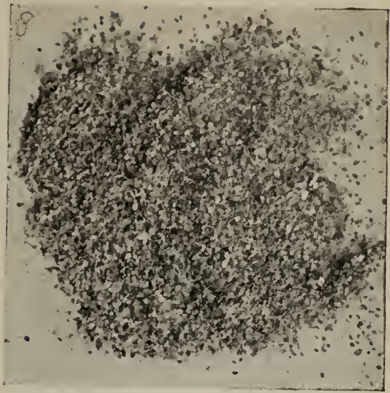


AUGUSTA, No. 1.
Size, 12-16.



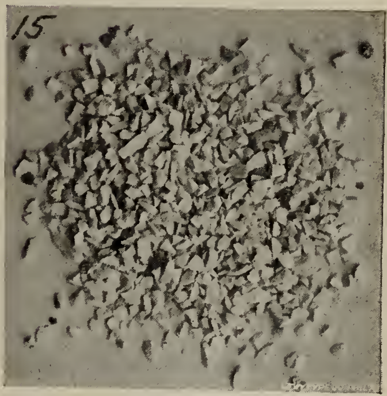
COCKSPUR BEACH.
Size, 70-80.

AUGUSTA, No. 2.
Size, 120-140.



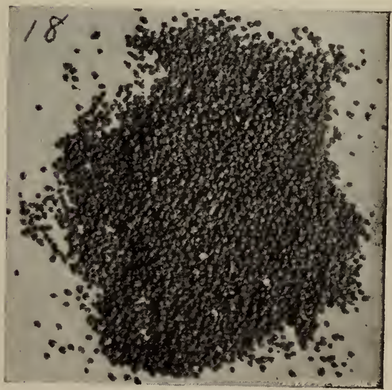
AUGUSTA, No. 2.
Size, 30-40.

FLORIDA LIMESTONE.
Size, 20-30.



FLORIDA LIMESTONE.
Size, 12-16.

RED SANDSTONE.
Size, 30-40.



RED SANDSTONE.
Size, 20-30.

Beach Sands.—The beach sands are much clearer and whiter than the river sands. But for some black particles, they would be as white as snow. They are quite sharp and apparently have a smaller percentage of rounded grains than the river sands. The sharp grains present edges and corners that appear to be worn a little smooth. The grade that passed the 140 sieve was just as sharp and free from dust or dirt as the coarser grades. (See Tables Nos. 8, 9 and 10.)

Tybee Bar.—This sand was taken from the outer bar at Tybee. It is practically identical with the beach sand, except that it contains more black particles and a little larger percentage of the very fine grades. (See Table No. 14.)

Cumberland Quicksand.—Under the microscope this sand looks about the same as beach sand, being a little whiter and clearer, and having more black grains in the lowest grade. The grading shows it to be a little coarser, but no difference was noticed as to sharpness. When wet it feels grating to the touch, as if it were glassy, and when thrown from hand to hand it makes a little noise, very much like the clucking of a hen. (See Table No. 17.)

Warsaw Quicksand.—This sand has all of the characteristics of the Cumberland quicksand, as has also the quicksand from St. John's Bar. (See Tables Nos. 16 and 18.)

Augusta, No. 1.—This sand is very similar to river sand, except that it has fewer rounded grains. It was taken from a pit in the Savannah River Valley, at Augusta. (See Table No. 13.)

Augusta, No. 2.—This was taken from the same pit as No. 1, and is practically identical with the beach sands in every particular, except as to color, being yellow instead of white. (See Table No. 15.)

Red Sandstone.—This sand was obtained by pulverising red sandstone. The grains have rounded edges and are covered with a dust of a reddish color, but are usually oblong in shape. Size 20–30 was not composed of individual grains, but was made up of smaller ones cemented together, and hence they have a very ragged surface. The size that passed 140 was mostly dust. (See Table No. 23.)

Brown Sandstone.—Was obtained in the same manner as

red sandstone, and was very similar to it. (See Table No. 22.)

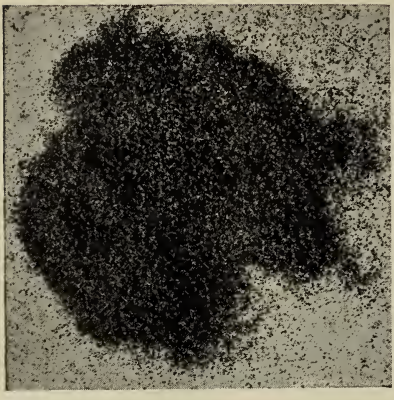
Florida Rock.—Was obtained by breaking up limestone from Florida. It was quite flinty, and broke up with extremely sharp edges. It was very light, and each grain had very smooth surfaces. (See Table No. 21.)

Trap Rock.—This was made from a very black and dense variety of trap rock, which was extremely hard to break. The surfaces of each grain were very rough. (See Table No. 19.)

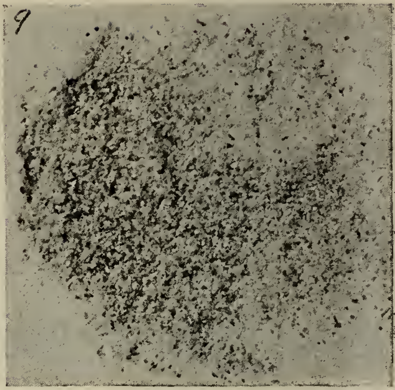
Granite.—This was obtained from a fine-grained, gray granite, which broke up in a similar manner to the trap rock. (See Table No. 20.)

The illustrations shown herewith comprise three grades of each sand. They have been reproduced to natural size, in all cases from a photograph of the material itself, in order to give a better idea of the comparative shape and size of grain of each sand than could be obtained from a description.

Results.—Generally speaking, the coarser the sand, the stronger the mortar made from it; but the difference between the grades below 30–40 are so slight that, as far as sizes are concerned, they might be considered in one class. There seemed to be a tendency towards an increase in strength with grades below 100–120, but so few samples of these grades were obtained that this slight increase may be put down as accidental. There is an unmistakable indication of weakness in the upper grade, 8–12. In the tables, about two cases out of three give 12–16 as stronger than 8–12; and there is but one case, where 8–12 is the highest, that cannot be accounted for by there being more water in this grade than in the next one. The shape and condition of the surface of sands, however, has much to do with the strength, as will be seen from the results obtained from the various crushed rocks. (See Tables Nos. 19 to 23, inclusive.) The Florida rock, which broke up into the sharpest sand of all, was not as good as some of the natural sands, probably owing to extremely smooth surfaces. Trap rock was not as sharp as the Florida rock, but gave much better results on

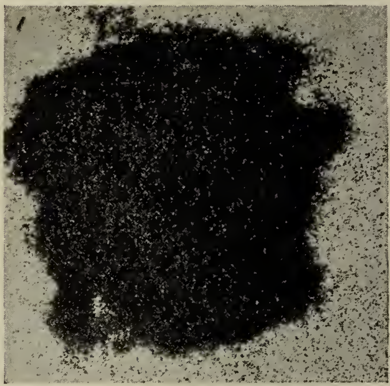


CUMBERLAND QUICKSAND.
Size, passed 140.



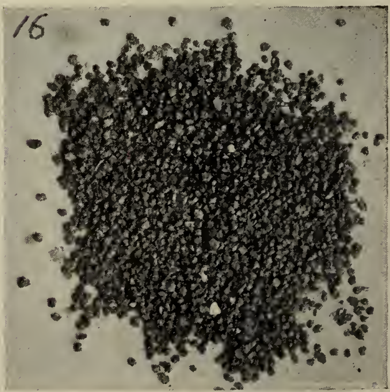
CUMBERLAND QUICKSAND.
Size, 40-50.

CUMBERLAND QUICKSAND.
Size, 30-40.

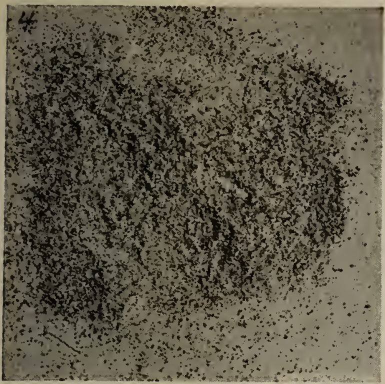


BROWN SANDSTONE.
Size, 120-140.

BROWN SANDSTONE.
Size, 20-30.

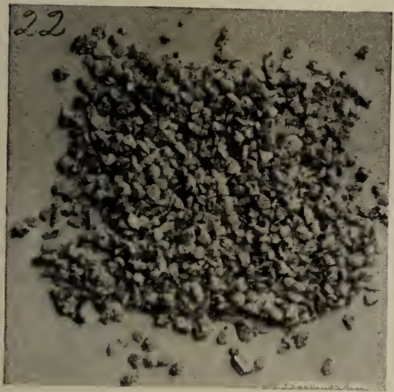


BROWN SANDSTONE.
Size, 16-20.

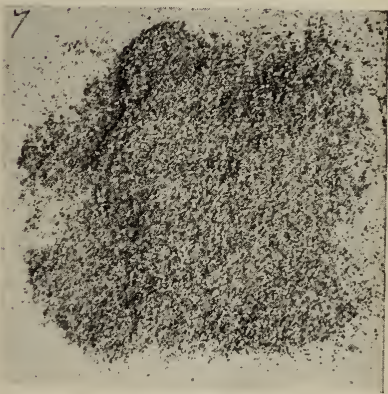


GRANITE
Size, 80-100.

GRANITE.
Size, 20-30.

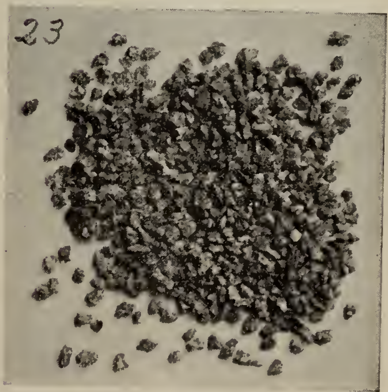


GRANITE.
Size, 12-16.



TRAP ROCK.
Size, 70-80.

TRAP ROCK.
Size, 20-30.



TRAP ROCK.
Size, 12-16.

account of the surfaces of the grains being very rough. The granite was about the same as the trap rock. The comparison of the beach and river sands, with but few exceptions, has proven the latter to be the best for cement mortar by from 2 to 10 per cent. After the grade of 40–50 is reached in the river sands, there is no practical difference between them and the beach sands. These two sands were compared by taking equal parts of sand and cement, by measure, and the result was the same as when taken by weight. The first set of experiments, in which it was found that the beach sand was the best, was unquestionably wrong; and there is no way of explaining how such a result was obtained. Greater ratios than 1 to 1 were tried (see Table, No. 25), mainly to test these two sands; and in this table the difference was found to be less noticeable. Col. Poe, in his work, found differences, due to different kinds of sand, to be greatest in mortar, where the least cement was used, and, as he did more work in that line than the writer, he may be right. The ratio of 1 to 1 was chosen for this work, however, on the supposition that it was the best for the purpose intended.

The only other series in the same line as the body of this work, that the writer could find to compare with, was that of Mr. Paul Alexandre, chief engineer of roads and bridges, France, published in "Annales des Ponts et Chaussées," 1892. His results, as far as they go, are the same as those here recorded except that his upper grade proved to be the maximum. This grade contained average grains a little coarser than the writer's upper grade, but also had a greater range of sizes; besides, the next lower grade was considerably smaller than the writer's second grade. The lowest grade was about equal to the writer's 50-60 grade, and, in the light of the present results, was quite low enough.

In Table No. 4 the weights of equal volumes of various kinds and grades of sand, poured loosely into a measure, are given, From Table No. 5 it is apparent that the specific gravity of all of these various kinds and grades of sand are not materially different, and that, therefore, the difference found between the weights of equal volumes (Table No. 4)

are principally due to different percentages of voids. It is further apparent from Table No. 5 that the smaller the grade the greater the percentage of voids in loose sand, and *vice versa;* while in well-packed sand there is practically no difference in percentage of voids. These results indicate that uniformity of mortar briquettes for tests can be obtained only by either measuring the sand while well packed, or by weighing.

CONCLUSIONS.

(1) Other things being equal, coarse sands are better than fine sands for cement mortar up to the grade 12–16, or about $\frac{1}{12}$ of an inch in diameter. (2) Below the grade 40–50, or about $\frac{1}{60}$ of an inch in diameter, there is no practical difference in the value of the different sands, as far as the size is concerned. (3) The shape and condition of the surfaces of the grains of different sands has as much to do with their value for cement mortar as the size.

SAVANNAH, GA., July 1, 1895.

TABLE No. 1.—GIVING FINENESS OF CEMENTS USED.

CEMENT.	Size of Sieves.	Per Cent. of Cement Passed.	CEMENT.	Size of Sieves.	Per Cent. of Cement Passed.
Brooklyn Bridge .	50	94·6	Norton	50	97·8
" " .	70	89·	"	70	87·5
" " .	100	69·	"	100	40·
Dyckerhoff . . .	50	99·7	Milwaukee . . .	50	94·5
" . . .	70	99·	"	70	88·
" . . .	100	89·	"	100	72·
" . . .	120	82·	Giant	70	99·
Alsen	70	97·8	"	100	91·3
" . . .	100	97·7	Louisville	50	92·5
"	120	93·	"	70	87·5
"	140	90·	"	100	70·
Hoffman	50	90·6			
"	70	87·5			
"	100	40·			

TABLE No. 2.—SHOWING SIEVES USED AND GRADES OF SANDS OBTAINED BY THEIR USE.

No. of Sieves.	No. of Wires in One Direction.	No. of Wires in Opposite Direction.	No. of Wire.	Size of Wire.	Size of Openings.	Grade of Sands.	Mean Size of Grains.
8	8	8	23	·025	·1000	8–12	·0830
12	12	12	28	·0165	·0670	12–16	·0560
16	16	16	28	·0165	·0460	16–20	·0420
20	19	20	30	·01375	·0388	20–30	·0310
30	29	30	32	·01125	·0232	30–40	·0200
40	36	40	33	·01025	·0175	40–50	·0150
50	45	48	34	·00950	·0125	50–60	·0110
60	52	60	35	·00900	·0102	60–70	·0095
70	55	69	36	·00750	{·0106 ·0070}	70–80	·0078
80	79	80	38	·00575	·0069	80–100	·0064
100	95	100	40	·00450	·0060	100–120	·0057
120	120	120	45	·00290	·0054	120–140	·0050
140	140	140	46	·00240	·0047	P. 140	{Below ·0047}

TABLE No. 3.—GIVING PER CENTS. OF EACH GRADE FOUND IN RIVER SAND AND COCKSPUR BEACH SAND.

Grade.	Per Cent. Found.	Grade.	Per Cent. Found.	Grade	Per Cent. Found.
River Sand, No. 1.		River Sand, No. 2.		Cockspur Beach.	
		8–12	3·2		
12–16	3·4	12–16	6·0	60–70	1·7
16–20	1·6	16–20	6·0	70–80	36·7
20–30	14·0	20–30	19·7	80–100	41·7
30–40	41·5	30–40	24·5	100–120	13·3
40–50	28·0	40–50	19·0	120–140	4·1
50–60	7·0	50–60	14·4	P. 140	2·5
60–70	1·6	60–70	2·1		100·0
70–80	2·6	70–80	4·7		
P. 80	0·3	P. 80	0·4		
	100·0		100·0		

TABLE No. 4.—GIVING WEIGHTS OF 24 CUBIC INCHES OF DIFFERENT KINDS AND GRADES OF SAND (SAND POURED LOOSELY INTO CUP).

Kind of Sand.	Grade.	Weight of 24 Cubic Inches in Ounces.	Kind of Sand.	Grade.	Weight of 24 Cubic Inches in Ounces.
River Sand, No. 1 . .	8–12	20⅛	Augusta, No. 2 . . .	40–50	16¾
" " . .	12–16	19⅝	Red Sandstone . . .	70–80	18
" " . .	16–20	19½	St. John Bar, Quicks'd	All	16¾
" " . .	20–30	19⅛	Florida Rock	8–12	16
" " . .	30–40	18⅝	Trap "	8–12	20
" " . .	40–50	18⅛	" "	12–16	19¾
" " . .	50–60	18¼	" "	P. 100	17½
" " . .	60–70	18⅝	Granite	8–12	18½
" " . .	70–80	18⅜	"	12–16	17¼
Augusta, No. 1	20–30	18½			
" "	12–16	18¾			
" "	30–40	18			
" No. 2	70–80	18			
Cockspur Beach . . .	All	18¼			
Tybee Beach, No. 2 .	20–30	19⅝			
River Sand, No. 2 . .	30–40	18⅞			

TABLE No. 5.—SHOWING THE VOIDS IN DIFFERENT SIZES OF SANDS; ALSO SPECIFIC GRAVITY.

1	2	3	4	5	6	7	8	9	10	11	12
SIZE OF SAND.	Weight of Bottle.	Weight of Bottle and Dry Sand Loose.	No. 3, with Water Added.	Per Cent. of Voids in Loose Sand.	Specific Gravity Derived from 2, 3 and 4.	Weight of Glass.	Glass and Dry Sand Loose.	No. 8, After Having Been Shaken Down and More Sand Added.	No. 9, After Adding Water.	Voids from 7, 9 and 10.	Specific Gravity from 7, 9 and 10.
				River Sand.							
	oz.	*oz.*	*oz.*			*oz.*	*oz.*	*oz.*	*oz.*		
8–12	8½	20⅛	23⅝	43·7	2·58	8⅜	19¾	20½	23⅞	42·2	2·62
12–16	8½	19¾	23½	45·6	2·64	8⅜	19⅝	20⅝	24	42·2	2·65
16–20	8½	19½	23¼	45·6	2·60	8⅜	19½	20⅝	24	42·2	2·65
20–30	8½	19¼	23⅛	48·4	2·60	8⅜	19⅜	20⅝	24	42·2	2·65
30–40	8½	19	23	50·0	2·62	—	—	—	—	—	—
40–50	8½	18⅝	22¾	51·5	2·61	8⅜	18¾	20½	23⅞	42·2	2·62
50–60	8½	18⅝	22¾	51·5	2·61	8⅜	19	20⅝	24	42·2	2·65
60–70	8½	18¾	22¾	50·0	2·56	8⅜	18⅞	20⅝	24⅛	43·8	2·72
70–80	8½	18⅞	22⅞	50·0	2·59	8⅜	18⅞	20⅝	24	42·2	2·65
				Cockspur Beach Sand.							
70–80	—	—	—	—	—	8⅜	18⅛	20	23½	43·8	2·64
80–100	—	—	—	—	—	8⅜	18½	20½	23⅞	42·2	2·62
100–120	—	—	—	—	—	8⅜	18¾	20⅝	24	42·2	2·62
120–140	—	—	—	—	—	8⅜	18⅞	20¾	24⅛	42·2	2·60

NOTE.—Both bottle and glass contained 14 cubic inches, and, when level full, each would hold 8 ounces of water (artesian).

TABLE No. 6.—VARIATION OF WATER.

CEMENT.	Kind of Sand.	Size of Sand.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
					No. of Tests.	Mean Strain.	Greatest Dif. from Mean.	No. of Tests.	Mean Strain.	Greatest Dif. from Mean.
Brooklyn Bridge .	Tybee Beach	80–100	Apr. 6	16·4	4	24	3	4	78	12
" " .	" "	80–100	" 6	12·7	4	24	3	4	70	4
" " .	" " No. 2 . .	20–30	" 6	11·3	4	35	6	4	80	8
" " .	" " " . .	20–30	" 6	12·7	4	42	3	4	93	14
" " .	" " " . .	20–30	" 6	14·2	4	42	2	4	107	7
" " .	" " " . .	20–30	" 6	14·9	4	48	3	4	119	14
" " .	" " " .	20–30	" 6	16·4	4	41	2	4	131	11
" "	Cumberland Quicks'd	70–80	" 6	14·9	3	37	1	4	91	10
" " .	" "	70–80	" 6	16·4	4	31	2	4	107	5
" " .	" "	70–80	" 6	18·0	4	28	3	4	117	10

TABLE No. 7.—VARIATION OF PRESSURE.

CEMENT.	Kind of Sand.	Size of Sand.	Pressure Per Square Inch.	Per Cent. Water.	Date Mixed.	7 DAYS.			56 DAYS.		
						No. of Tests.	Mean Strain	Greatest Dif. from Mean.	No. of Tests.	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	Tybee Beach . .	80–100	H. T.	12·7	Mar. 26	4	161	18	3	228	13
"	" "	80–100	675	12·7	" 26	4	129	10	4	152	6
"	" "	All	H. T.	12·7	" 26	4	172	17	4	186	40
"	" "	"	675	12·7	" 26	4	148	8	4	202	29
"	River Sand, C. R. . .	30–40	H. T.	11·9	" 26	3	239	20	4	247	38
"	" " . .	12–16	"	11·2	" 26	3	233	7	4	236	14
" . . .	" " .	12–16	675	12·5	" 26	2	307	8	2	298	18
"	Cockspur Beach . . .	All	1,000	11·9	Apr. 1	4	142	15	3	213	9
"	" " . . .	"	200	11·9	" 1	4	98	6	4	176	12
"	River Sand, C. R. . .	20–30	1,000	11·2	" 1	3	198	20	4	286	11
"	" " . . .	20–30	200	11·9	" 1	4	146	18	4	221	5
Hoffman	Cockspur Beach . . .	All	1,000	16·4	Mar. 30	3	41	4	4	128	18
"	" " . . .	"	H. T.	16·4	" 29	4	37	3	4	133	15
"	" " . .	"	770	16·4	" 29	4	36	3	4	115	19
"	" " . . .	"	1,000	16·4	Apr. 1	3	35	6	4	122	11
"	" " . . .	"	770	16·4	" 1	4	34	2	3	115	11
"	" " . . .	"	425	16·4	" 1	4	28	2	3	90	11
"	" " . . .	"	200	16·4	" 1	4	26	3	4	94	5
"	River Sand, C. R. . .	20–30	1,000	14·2	Mar. 30	3	57	2	4	146	17
"	" " . .	20–30	770	14·9	" 29	3	48	7	4	130	7
"	" " . .	20–30	H. T.	14·9	" 29	4	45	4	4	106	17
"	" " . .	20–30	1,000	14·9	Apr. 1	4	56	3	3	126	7
" . . .	" " . .	20–30	770	14·9	" 1	4	54	4	3	125	14
"	" " . .	20–30	425	14·9	" 1	4	47	4	3	114	8
"	" " . .	20–30	200	14·9	" 1	4	33	5	4	100	11

NOTE.—H. T. means hand-tamped by the method previously described.

TABLE No. 8.—Cockspur Beach.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff . . .	All	Mar. 12	13·5	3	119	2	5	197	18
"	60–70	" 14	14·3	—	—	—	2	218	2
"	70–80	" 14	14·2	4	126	13	4	201	4
"	80–100	" 14	14·2	4	134	3	4	209	10
"	100–120	" 14	14·1	4	136	21	5	201	11
"	120–140	" 14	14·5	3	139	10	4	226	38
"	Passed 140	" 14	12·5	1	152	—	2	183	6
Giant	70–80	" 14	14·2	4	124	12	4	215	8
"	All	" 13	14·0	4	134	3	4	229	13
"	Held by 100	" 15	14·2	4	141	16	4	212	9
Alsen	All	" 13	15·5	3	186	9	4	262	15
Louisville	"	" 13	17·1	4	34	4	4	137	12
Norton	"	" 13	16·0	4	28	2	4	97	7
Brooklyn Bridge .	"	" 13	15·0	4	27	1	4	89	7
Hoffman	"	" 13	16·0	4	26	2	4	100	8
Milwaukee	80–100	" 14	19·4	4	34	2	4	90	14
"	All	" 13	17·1	—	—	—	4	80	9
"	Held by 100	" 15	20·0	4	32	2	4	91	4
Brooklyn Bridge .	100–120	" 14	16·0	5	21	1	4	91	10
" " .	80–100	" 14	16·4	4	23	2	4	88	6
" " .	Held by 100	" 15	16·4	4	24	0	4	99	2
Hoffman	70–80	" 14	16·4	4	23	2	4	100	9
"	Held by 100	" 15	16·4	4	25	1	4	91	6
Louisville	70–80	" 14	19·4	4	70	6	4	135	7
"	Held by 100	" 15	19·4	4	70	5	5	132	5
Norton	" 100	" 15	16·4	4	27	5	4	96	6
"	70–80	" 14	16·4	4	23	3	4	107	5
"	80–100	" 14	16·4	4	23	2	4	94	12
"	100–120	" 14	16·2	4	25	2	5	105	17
"	120–140	" 14	17·3	2	20	2	3	97	7
"	Passed 140	" 14	16·0	—	—	—	2	100	11

TABLE No. 9.—Tybee Beach, No. 1.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	50–60	Mar. 26	11·7	—	—	—	2	182	14
"	60–70	" 26	13·1	—	—	—	2	181	11
"	70–80	" 26	12·6	4	95	5	4	159	15
"	80–100	" 26	12·6	4	107	13	4	183	14
"	100–120	" 26	13·5	—	—	—	3	162	5
"	All	" 26	12·6	4	110	5	4	178	10
Giant	60–70	" 23	13·5	1	112	—	2	201	2
"	70–80	" 23	13·7	2	114	1	3	176	39
"	80–100	" 23	13·7	2	127	5	3	202	9
"	100–120	" 23	13 7	2	125	8	3	191	5
"	120–140	" 23	15·0	2	129	4	3	203	12
"	Passed 140	" 23	15·3	2	117	2	3	196	23
"	All	" 23	14·2	4	130	8	4	189	8
Brooklyn Bridge .	70–80	" 23	16·4	4	24	3	4	89	4
" " .	80–100	" 23	16·4	3	22	2	4	84	11
" " .	100–120	" 23	16·4	5	20	3	4	78	8
" " .	120–140	" 23	14·3	—	—	—	1	97	—
" " .	All	" 23	16·4	4	22	1	4	90	3
Louisville	7 –80	" 21	21·0	4	61	6	4	129	13
Hoffman	70–80	" 29	16·4	4	28	2	4	104	8
"	80–100	" 29	16·4	4	28	3	4	92	8
"	100–120	" 29	15·1	2	34	2	2	84	3
"	120–140	" 29	16·2	—	—	—	3	90	5
"	Passed 140	" 29	22·4	—	—	—	2	110	3
Dyckerhoff	70–80	Apr. 4	12·7	4	128	3	4	183	30
"	70–80	" 6	12 7	3	109	10	4	164	7

TABLE No. 10.—TYBEE BEACH, No. 2.

CEMENT	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Brooklyn Bridge .	16–20	Apr. 4	14·3	—	—	—	2	54	20
" " .	20–30	" 4	15·0	4	39	6	4	100	14
" " .	30–40	" 4	15·0	4	39	2	4	100	4
" " .	40–50	" 4	14·3	—	—	—	2	76	1
" " .	50–60	" 4	15·3	—	—	—	2	94	3
" " .	60–70	" 4	16·7	—	—	—	1	86	—
" " .	70–80	" 4	15·7	4	28	4	4	79	5
" " .	80–100	" 4	15·7	4	20	1	4	72	6
" " .	100–120	" 4	16·0	2	24	1	3	80	9
" " .	120–140	" 4	13·2	—	—	—	1	67	—

TABLE No. 11.—RIVER SAND, No. 1.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	8–12	Mar. 14	12·5	—	—	—	1	332	—
"	12–16	" 15	9·7	2	189	4	2	232	3
"	16–20	" 15	10·0	2	173	2	2	195	10
"	20–30	" 15	11·5	2	158	1	3	212	1
"	30–40	" 16	11·2	4	150	9	4	177	20
"	40–50	" 16	12·0	4	147	13	4	187	10
" . . .	50–60	" 15	12·0	4	137	13	4	190	8
"	60–70	" 15	11·1	2	144	3	2	187	3
" . . .	70–80	" 15	11·1	4	119	9	—	—	—
"	All	" 12	14·0	4	162	28	5	218	17
Giant	20–30	" 16	13·3	2	191	8	3	267	16
"	30–40	" 16	14·5	4	145	9	4	190	12
"	40–50	" 16	14·5	4	138	15	4	194	12
"	All	" 13	13·3	3	158	8	4	245	36
Alsen	"	" 13	14·4	3	254	22	4	269	32
Louisville	"	" 13	17·3	4	62	7	4	128	12
"	20–30	" 16	20·0	2	81	1	3	144	34
"	30–40	" 16	17·2	—	—	—	8	123	19
Milwaukee	20–30	" 15	20·7	2	42	—	4	129	1
"	30–40	" 16	16·0	3	37	6	4	100	8
"	40–50	" 16	22·0	2	34	2	2	113	5
"	All	" 13	16·4	3	37	5	4	104	9
Norton	20–30	" 15	15·0	2	35	2	3	105	12
"	30–40	" 16	14·2	4	31	4	4	91	11
"	40–50	" 16	14·2	4	34	1	4	95	16
"	50–60	" 15	15·0	4	33	—	4	103	8
"	All	" 13	16·4	4	36	3	4	114	10
Brooklyn Bridge .	20–30	" 15	15·2	2	35	1	3	107	11
" " .	30–40	" 16	14·2	4	32	3	4	86	11
" " .	40–50	" 16	14·2	4	31	2	4	82	5
" " .	50–60	" 15	16·0	—	—	—	2	85	3
" " .	All	" 13	14·3	4	33	1	2	101	7
Hoffman . .	20–30	" 16	14·1	2	35	1	3	92	5
"	30–40	" 16	14·2	4	32	5	4	83	9
"	40–50	" 15	14·2	4	34	1	4	95	8
"	All	" 13	16·0	4	25	4	2	110	19

TABLE No. 12.—River Sand, No. 2.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days. No. of Tests	7 Days. Mean Strain.	7 Days. Greatest Dif. from Mean.	56 Days. No. of Tests	56 Days. Mean Strain.	56 Days. Greatest Dif. from Mean.
Dyckerhoff	12–16	Mar. 25	11·2	3	157	2	4	198	10
"	16–20	" 25	11·6	3	157	12	4	224	29
"	20–30	" 25	11·9	4	153	8	4	200	6
" . . .	30–40	" 25	11·9	4	140	18	4	161	17
"	30–40	" 19	11·9	4	154	9	4	183	31
"	40–50	" 25	11·9	4	124	2	4	166	14
Giant	8–12	" 22	12·8	3	108	20	3	153	21
"	12–16	" 22	11·9	3	135	13	4	185	14
"	16–20	" 22	11·9	3	139	13	4	188	18
"	20–30	" 22	11·9	3	149	13	4	182	18
"	30–40	" 22	12·6	4	139	4	4	175	18
"	30–40	" 19	11·9	3	144	9	4	189	9
"	40–50	" 22	13·4	4	140	7	4	178	18
"	50–60	" 22	1[illegible]·3	2	134	4	2	209	10
Louisville	8–12	" 21	19·8	4	69	12	4	99	20
"	12–16	" 21	19·8	4	88	13	4	140	19
"	16–20	" 21	17·9	4	66	8	4	106	14
"	20–30	" 21	18·7	4	66	1	4	123	10
"	30–40	" 21	19·8	4	76	3	4	130	18
" . . .	40–50	" 21	19·8	4	63	4	4	111	6
"	50–60	" 21	20·2	4	61	7	4	106	18
"	60–70	" 21	18·5	1	52	—	2	101	14
Hoffman	16–20	" 29	14·5	3	41	3	3	107	7
"	20–30	" 29	14·2	4	42	6	3	105	12
"	30–40	" 29	14·2	4	37	2	4	94	3
Norton	16–20	" 28	14·2	4	39	5	4	111	8
"	20–30	" 28	14·2	4	38	2	4	98	5
"	30–40	" 28	14·9	4	35	2	4	100	9
"	40–50	" 28	15·7	4	3	2	4	88	2
Brooklyn Bridge .	12–16	" 23	13·4	4	32	3	4	98	11
" " .	16–20	" 23	14·2	4	3[illegible]	4	4	91	3
" " .	20–30	" 23	14·2	4	35	2	4	102	13
" " .	30–40	" 23	15·0	4	34	2	4	92	6
" " .	30–40	" 19	14·2	3	31	3	4	92	4
" " .	40–50	" 23	15·0	4	26	1	4	81	10

TABLE No. 13.—Augusta, No. 1.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days. No. of Tests	7 Days. Mean Strain.	7 Days. Greatest Dif. from Mean.	56 Days. No. of Tests	56 Days. Mean Strain.	56 Days. Greatest Dif. from Mean.
Dyckerhoff	8–12	Apr. 11	11·8	2	202	7	3	231	20
"	12–16	" 11	11·6	3	257	17	4	289	24
"	16–20	" 11	11·6	3	240	9	4	273	24
" . .	20–30	" 11	12·3	3	242	11	4	278	22
"	30–40	" 11	12·3	3	204	11	4	259	23
"	40–50	" 11	13·1	—	—	—	4	247	21
"	Passed 140	" 11	14·0	—	—	—	1	213	—
Norton	8–12	" 9	16·3	—	—	—	2	142	1
"	12–16	" 9	14·2	4	42	6	4	101	6
"	16–20	" 9	14·2	4	47	4	4	115	14
"	20–30	" 9	14·2	4	47	2	4	106	6
"	30–40	" 9	15·0	4	44	3	4	123	10
"	40–50	" 9	16·3	—	—	—	3	124	5
Brooklyn Bridge .	12–16	" 10	14·2	—	—	—	8	97	9
" " .	16–20	" 10	15·0	—	—	—	8	116	16
" " .	20–30	" 10	15·0	—	—	—	8	110	8
" " .	30–40	" 10	15·7	—	—	—	8	130	9
Hoffman	12–16	" 9	14·1	—	—	—	4	102	9
"	16–20	" 9	15·9	2	41	1	4	124	7
"	20–30	" 9	15·0	4	35	5	4	92	6
"	30–40	" 9	16·7	4	37	4	4	103	4

TABLE No. 14.—TYBEE BAR.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Strength.	Difference.
Dyckerhoff	All	Mar. 19	14·2	4	144	12	4	204	15
"	70–80	" 19	14·2	4	144	3	4	221	13
Giant	All	" 19	13·6	2	126	4	2	251	5
Louisville	80–100	" 21	20·1	4	60	13	5	128	20
"	100–120	" 21	20·0	2	62	6	3	142	2
Norton	All	" 19	16·4	4	30	3	4	103	13
"	70–80	" 19	16·3	2	28	1	3	126	15
"	80–100	" 28	16·4	4	29	3	4	106	5
"	100–120	" 28	14·3	2	31	3	3	89	4
"	120–140	" 28	13·5	1	35	—	2	83	—
"	Passed 140	" 28	—	—	—	—	2	99	3
"	½ (80–100) ½ (20–30 River sand.)	" 28	16·4	3	34	4	4	112	9
Brooklyn Bridge .	All	" 19	16·4	4	28	2	4	119	15

TABLE No. 15.—AUGUSTA, No. 2.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	30–40	Apr. 11	13·5	2	151	2	3	198	10
"	40–50	" 11	12·7	4	148	7	4	192	12
"	50–60	" 11	12·7	4	154	11	4	197	31
"	60–70	" 11	12·7	5	145	13	4	209	10
"	70–80	" 11	13·1	4	142	9	4	203	35
"	80–100	" 11	12·9	—	—	—	4	211	15
"	100–120	" 11	10·0	—	—	—	1	210	—
"	Passed 140	" 11	12·5	—	—	—	1	206	—
Brooklyn Bridge .	50–60	" 10	16·4	—	—	—	8	97	18
" " .	70–80	" 10	16·4	—	—	—	8	92	10

TABLE No. 16.—WARSAW QUICKSAND.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	60–70	Apr. 4	11·0	—	—	—	1	228	—
"	70–80	" 4	12·7	4	157	10	4	194	27
"	80–100	" 4	11·6	2	150	7	3	183	20

TABLE No. 17.—CUMBERLAND QUICKSAND.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	70–80	Apr. 6	12·7	4	150	13	4	174	28
"	80–100	" 6	12·1	—	—	—	3	179	11
Norton	40–50	" 6	25·0	—	—	—	1	69	—
"	50–60	" 6	19·2	—	—	—	2	101	13
"	60–70	" 6	17·1	—	—	—	5	116	12
"	70–80	" 6	15·7	4	36	4	4	101	6
"	80–100	" 6	15·7	4	40	3	4	101	7
"	100–120	" 6	13·3	—	—	—	1	70	—

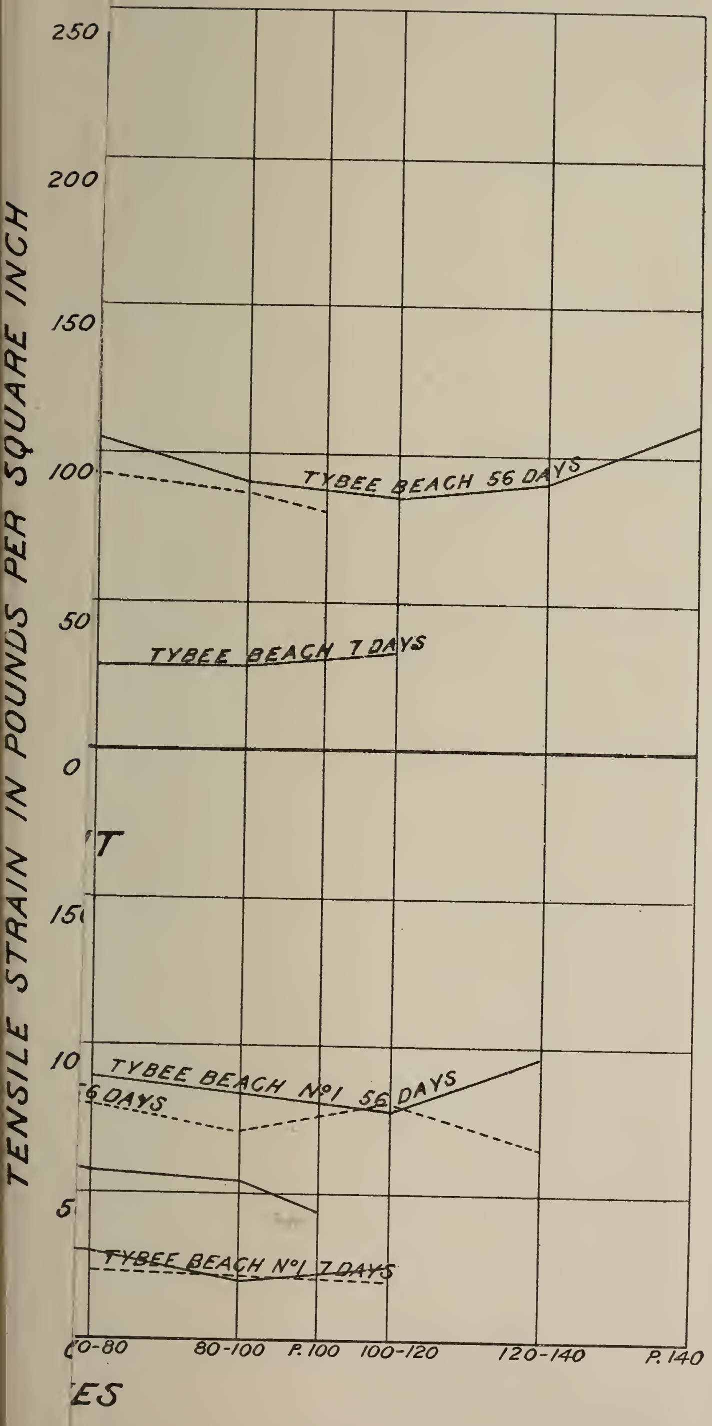
TABLE No. 18.—ST. JOHN'S BAR.

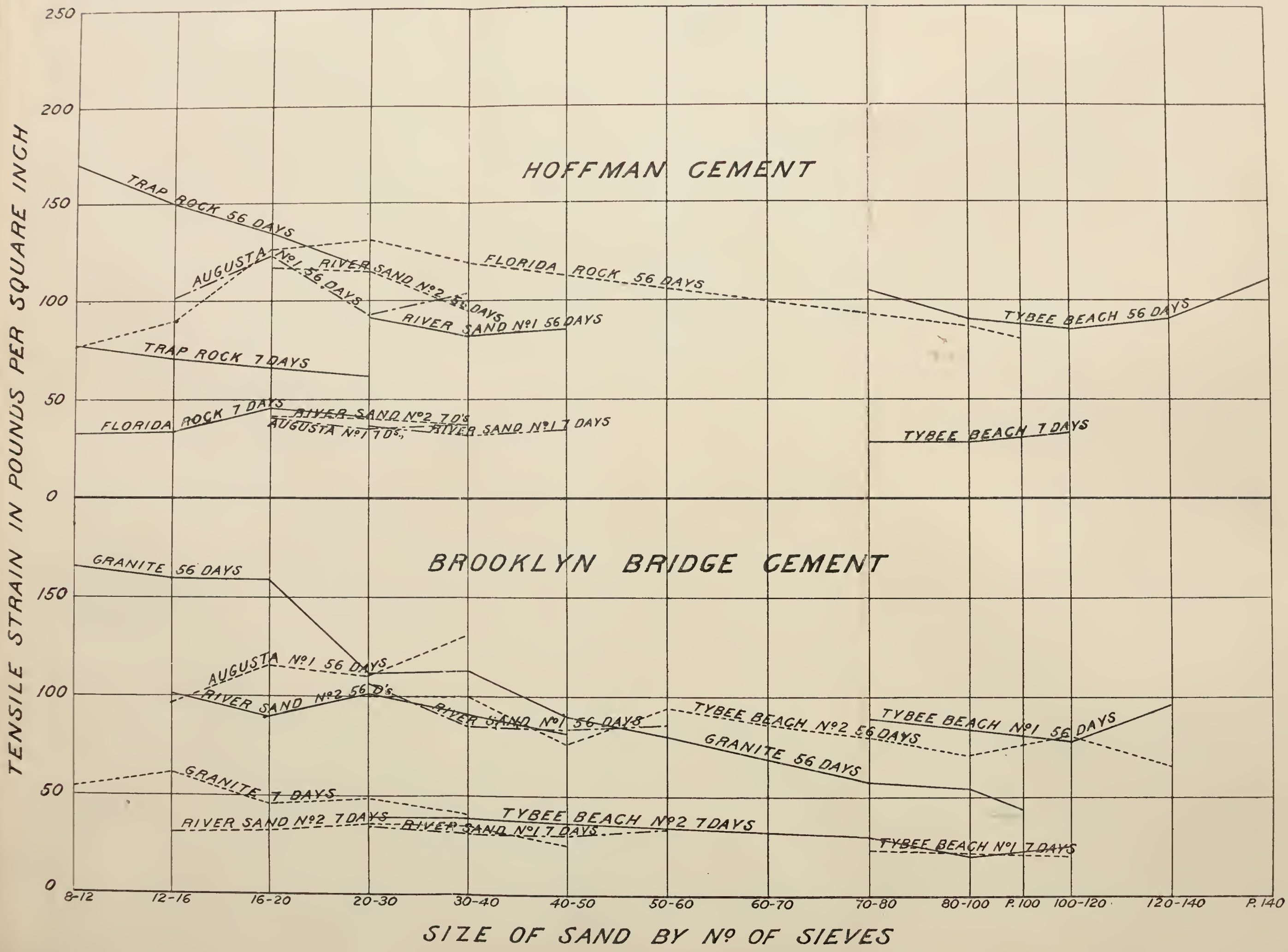
CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	7 –80	Apr. 25	13·2	—	—	—	1	151	—
"	80–100	" 25	9·1	—	—	—	4	190	11

TABLE No. 19.—TRAP ROCK.

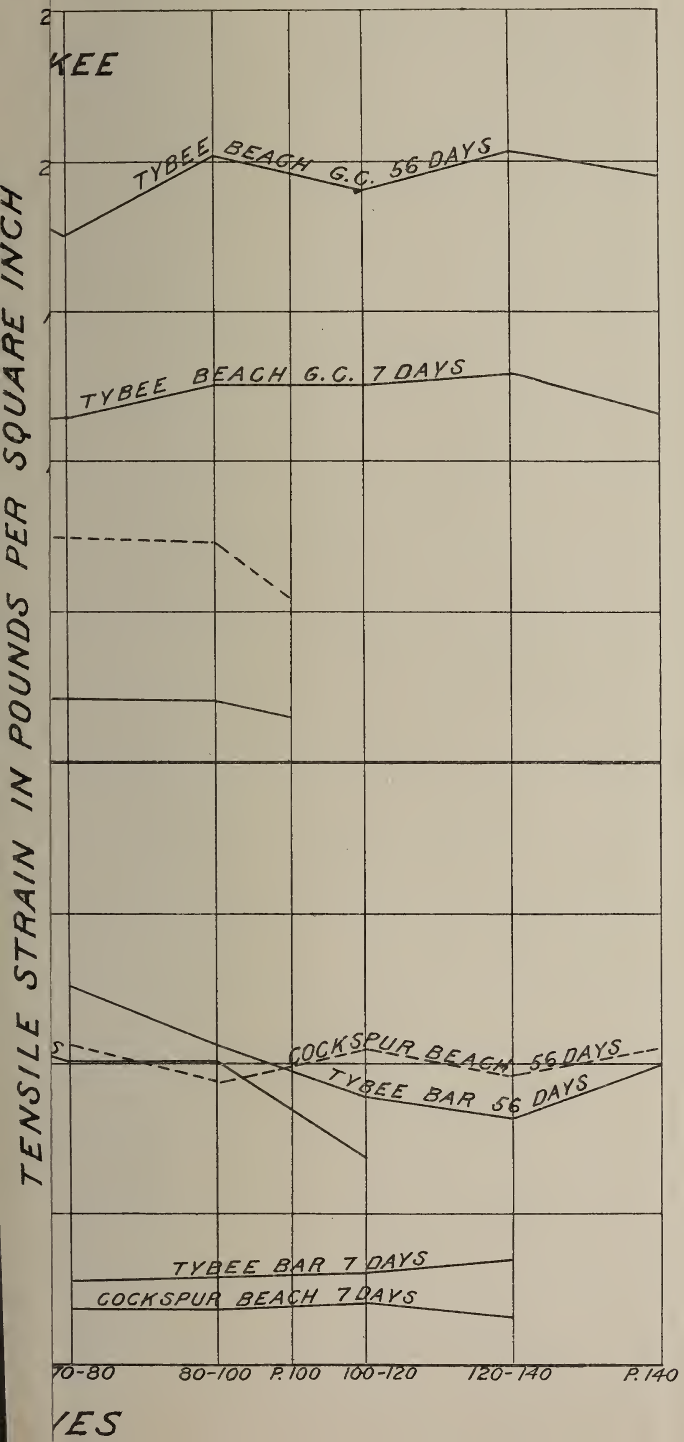
CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	8–12	Apr. 3	11·9	2	276	4	4	393	21
" . . .	12–16	" 3	11·9	2	256	1	4	428	23
"	16–20	" 3	11·9	3	232	5	4	363	24
"	20–30	" 3	11·9	3	196	8	4	349	13
"	30–40	" 3	12·7	4	178	12	4	290	25
"	40–50	" 3	11·5	2	143	5	2	273	20
"	50–60	" 3	12·5	2	136	2	2	262	8
"	60–70	" 3	12·5	—	—	—	2	248	2
"	70–80	" 3	13·3	3	136	8	3	231	19
"	80–100	" 3	11·1	1	111	—	2	241	7
" . . .	Passed 100	" 3	16·4	4	177	5	4	246	27
Hoffman	8–12	" 4	14·4	3	77	9	5	170	18
"	12–16	" 4	14·8	4	70	6	4	151	15
"	16–20	" 4	13·3	—	—	—	1	135	—
"	20–30	" 4	17·5	3	60	2	3	114	30
"	Passed 100	" 4	21·0	4	22	2	4	60	9
Brooklyn Bridge	8–12	" 4	14·2	4	62	8	4	156	9
" " .	12–16	" 4	14·2	4	60	6	4	166	28

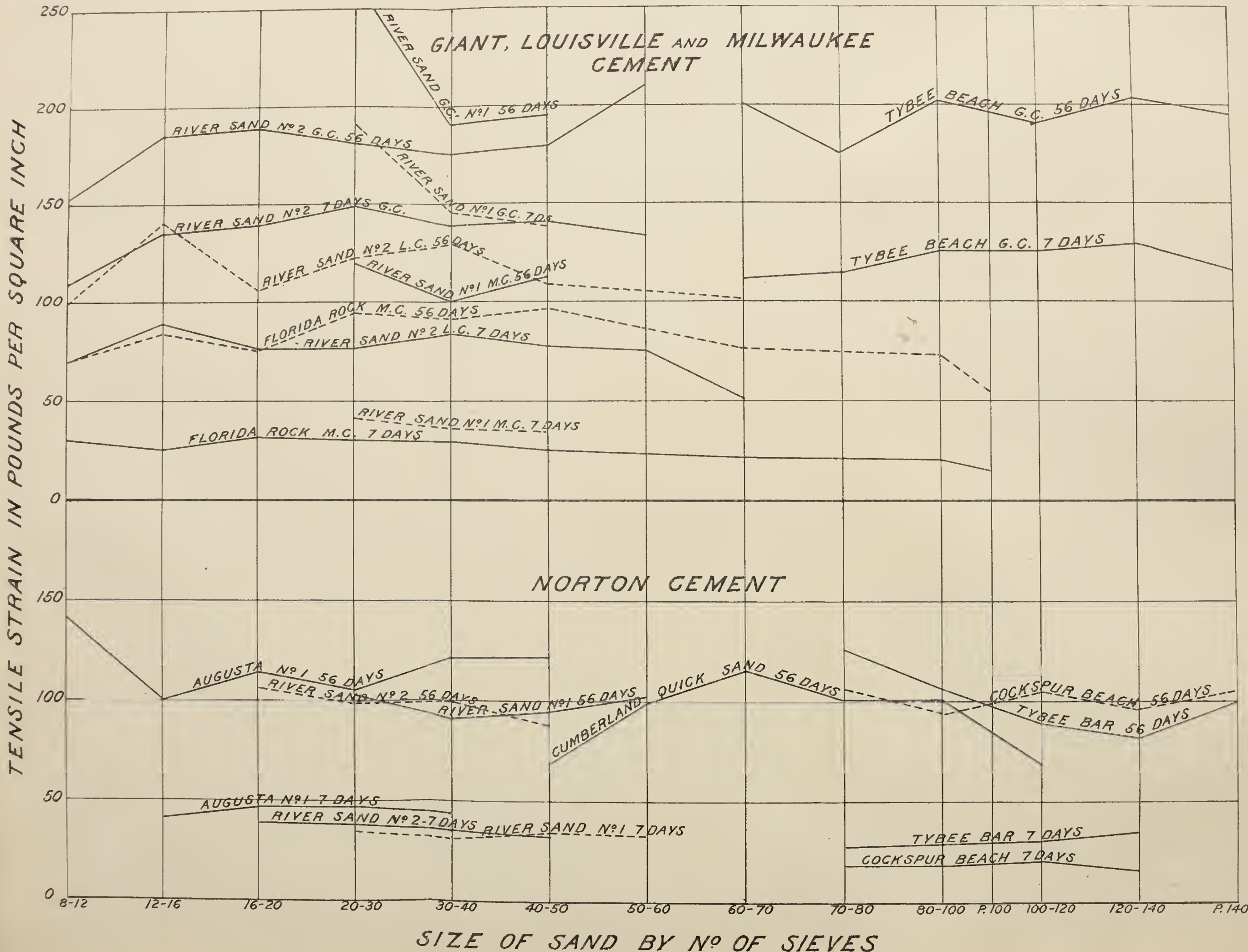
(Cooper.)


TENSILE STRAIN IN POUNDS PER SQUARE INCH
250
200
150
100
50
0
T
10
TYBEE BEACH 56 DAYS
TYBEE BEACH 7 DAYS
TYBEE BEACH N°1 56 DAYS
TYBEE BEACH N°1 7 DAYS
80-100
P. 100
100-120
120-140
P. 140
ES

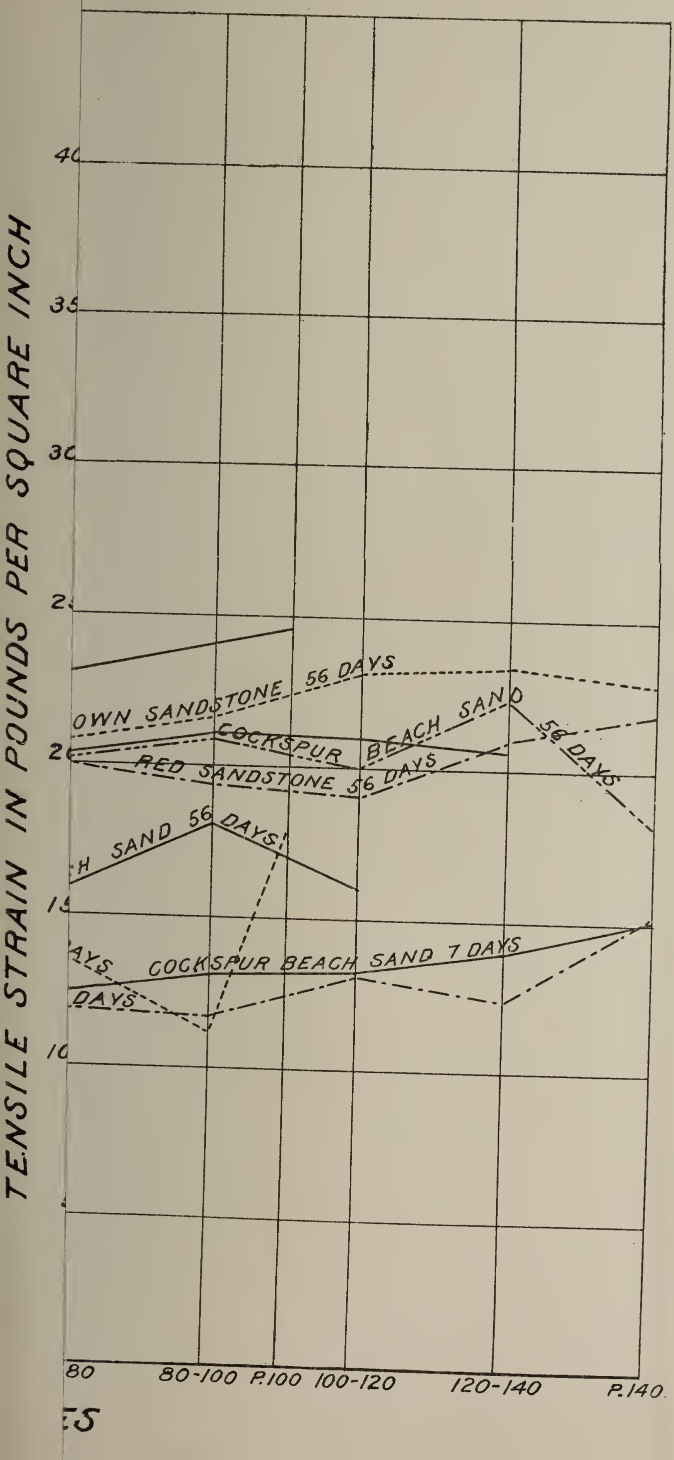

HOFFMAN CEMENT
BROOKLYN BRIDGE CEMENT
TENSILE STRAIN IN POUNDS PER SQUARE INCH
SIZE OF SAND BY Nº OF SIEVES
250
200
150
100
50
0
8-12
12-16
16-20
20-30
30-40
40-50
50-60
60-70
70-80
80-100
P.100
100-120
120-140
P.140
TRAP ROCK 56 DAYS
AUGUSTA Nº1 56 DAYS
RIVER SAND Nº2 56 DAYS
FLORIDA ROCK 56 DAYS
RIVER SAND Nº1 56 DAYS
TYBEE BEACH 56 DAYS
TRAP ROCK 7 DAYS
FLORIDA ROCK 7 DAYS
RIVER SAND Nº2 7 D'S
AUGUSTA Nº1 7 D'S
RIVER SAND Nº1 7 DAYS
TYBEE BEACH 7 DAYS
GRANITE 56 DAYS
AUGUSTA Nº1 56 DAYS
RIVER SAND Nº2 56 D'S
RIVER SAND Nº1 56 DAYS
TYBEE BEACH Nº2 56 DAYS
TYBEE BEACH Nº1 56 DAYS
GRANITE 56 DAYS
GRANITE 7 DAYS
RIVER SAND Nº2 7 DAYS
RIVER SAND Nº1 7 DAYS
TYBEE BEACH Nº2 7 DAYS
TYBEE BEACH Nº1 7 DAYS

(*Cooper.*)


KEE
TYBEE BEACH G.C. 56 DAYS
TYBEE BEACH G.C. 7 DAYS
COCKSPUR BEACH 56 DAYS
TYBEE BAR 56 DAYS
TYBEE BAR 7 DAYS
COCKSPUR BEACH 7 DAYS
TENSILE STRAIN IN POUNDS PER SQUARE INCH
70-80
80-100
P. 100
100-120
120-140
P. 140
VES


GIANT, LOUISVILLE AND MILWAUKEE CEMENT
NORTON CEMENT
TENSILE STRAIN IN POUNDS PER SQUARE INCH
SIZE OF SAND BY Nº OF SIEVES
250
200
150
100
50
0
8-12
12-16
16-20
20-30
30-40
40-50
50-60
60-70
70-80
80-100
P.100
100-120
120-140
P.140
RIVER SAND G.C. Nº1 56 DAYS
RIVER SAND Nº2 G.C. 56 DAYS
RIVER SAND Nº1 G.C. 7 DS
RIVER SAND Nº2 7 DAYS G.C.
RIVER SAND Nº2 L.C. 56 DAYS
RIVER SAND Nº1 M.C. 56 DAYS
FLORIDA ROCK M.C. 56 DAYS
RIVER SAND Nº2 L.C. 7 DAYS
RIVER SAND Nº1 M.C. 7 DAYS
FLORIDA ROCK M.C. 7 DAYS
TYBEE BEACH G.C. 56 DAYS
TYBEE BEACH G.C. 7 DAYS
AUGUSTA Nº1 56 DAYS
RIVER SAND Nº2 56 DAYS
RIVER SAND Nº1 56 DAYS
CUMBERLAND
QUICK SAND 56 DAYS
COCKSPUR BEACH 56 DAYS
TYBEE BAR 56 DAYS
AUGUSTA Nº1 7 DAYS
RIVER SAND Nº2-7 DAYS
RIVER SAND Nº1 7 DAYS
TYBEE BAR 7 DAYS
COCKSPUR BEACH 7 DAYS

(Cooper.)


TENSILE STRAIN IN POUNDS PER SQUARE INCH
40
35
30
25
20
15
10
OWN SANDSTONE 56 DAYS
COCKSPUR BEACH SAND
RED SANDSTONE 56 DAYS
56 DAYS
H SAND 56 DAYS
AYS
COCKSPUR BEACH SAND 7 DAYS
DAYS
80
80-100
P.100
100-120
120-140
P.140.
ES

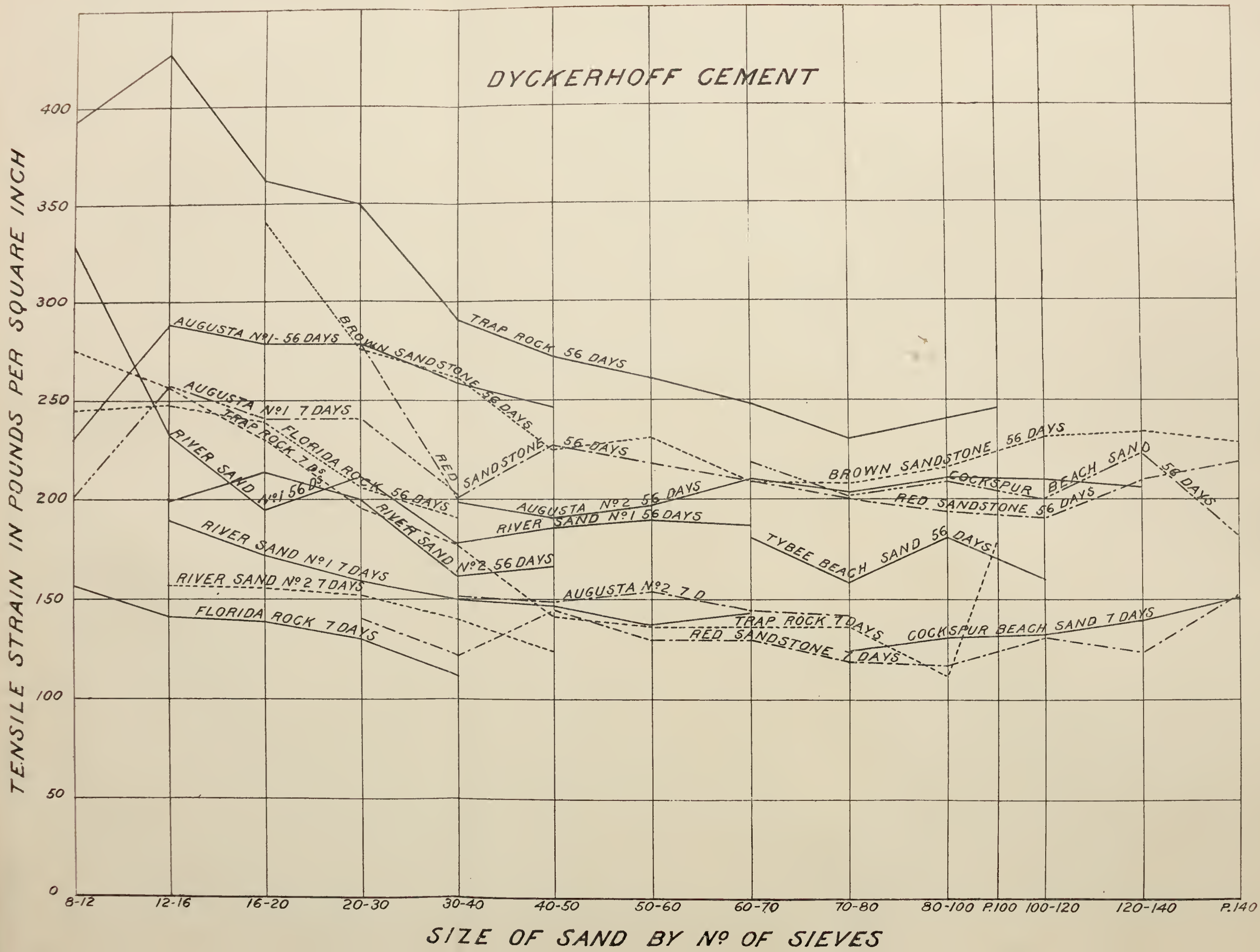

DYCKERHOFF CEMENT
TENSILE STRAIN IN POUNDS PER SQUARE INCH
400
350
300
250
200
150
100
50
0
AUGUSTA Nº1- 56 DAYS
BROWN SANDSTONE 56 DAYS
TRAP ROCK 56 DAYS
AUGUSTA Nº1 7 DAYS
TRAP ROCK 7 DS
FLORIDA ROCK 56 DAYS
RIVER SAND Nº1 56 D
RED SANDSTONE 56 DAYS
RIVER SAND Nº2 56 DAYS
AUGUSTA Nº2 56 DAYS
RIVER SAND Nº1 56 DAYS
BROWN SANDSTONE 56 DAYS
COCKSPUR BEACH SAND 56 DAYS
RED SANDSTONE 56 DAYS
TYBEE BEACH SAND 56 DAYS
RIVER SAND Nº1 7 DAYS
RIVER SAND Nº2 7 DAYS
AUGUSTA Nº2 7 D
FLORIDA ROCK 7 DAYS
TRAP ROCK 7 DAYS
RED SANDSTONE 7 DAYS
COCKSPUR BEACH SAND 7 DAYS
8-12
12-16
16-20
20-30
30-40
40-50
50-60
60-70
70-80
80-100
P.100
100-120
120-140
P.140
SIZE OF SAND BY Nº OF SIEVES

TABLE No. 20.—GRANITE.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Strength.	Difference.
Dyckerhoff	8–12	April 13	11·9	3	223	27	3	340	60
Brooklyn Bridge .	8–12	" 13	14·0	4	54	4	3	167	5
" " .	12–16	" 13	14·7	3	63	4	4	160	22
" " .	16–20	" 13	15·4	3	46	1	4	158	17
" " .	20–30	" 13	15·3	4	48	3	4	121	7
" " .	30–40	" 13	17·3	3	41	3	4	124	7
" " .	40–50	" 13	15·4	—	—	—	3	88	2
" " .	50–60	" 13	15·1	—	—	—	3	80	10
" " .	60–70	" 13	15·7	—	—	—	1	70	—
" " .	70–80	" 13	18·6	—	—	—	5	57	12
" " .	80–100	" 13	16·0	—	—	—	1	54	—
" " .	Passed 100	" 13	22·4	—	—	—	4	45	6

TABLE No. 21.—FLORIDA LIMESTONE.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif from Mean.	No. of Tests	Mean Strain	Greatest Dif. from Mean.
Dyckerhoff	8–12	Mar. 27	12·5	3	157	12	4	246	22
"	12–16	" 27	11·6	4	141	6	4	248	7
"	16–20	" 27	12·5	4	139	17	4	240	41
"	20–30	" 27	13·5	4	135	11	4	207	12
"	30–40	" 27	12·9	2	113	3	2	191	5
"	Passed 100	" 27	13·7	2	116	2	2	206	6
Milwaukee	8–12	" 27	16·4	4	30	4	4	69	7
"	12–16	" 27	16·7	4	26	2	4	85	13
"	16–20	" 27	18·4	4	32	5	4	75	7
"	20–30	" 27	19·2	4	30	3	4	95	7
"	30–40	" 27	19 9	4	29	4	4	91	6
"	40–50	" 27	22·5	3	26	2	4	96	11
"	50–70	" 27	22·5	3	22	3	4	76	5
"	70–100	" 27	22·5	3	20	2	4	73	10
"	Passed 100	" 27	22·3	3	16	2	4	55	11
Hoffman	8–12	" 28	14·3	3	33	1	4	77	18
"	12–16	" 28	14 5	4	34	5	4	89	13
"	16–20	" 28	14 8	2	46	4	3	126	15
"	20–30	" 28	16·0	3	40	4	4	131	17
"	30–40	" 28	17·4	—	—	—	3	119	11
"	70–100	" 28	20·0	—	—	—	2	87	6
"	Passed 100	" 28	23·3	2	17	0	2	82	11
Brooklyn Bridge .	8–12	Apr. 12	15·7	4	49	13	4	135	13

TABLE No. 22.—BROWN SANDSTONE.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	16–20	Apr. 5	13·8	—	—	—	1	341	—
"	20–30	" 5	12·3	4	170	26	4	275	24
"	30–40	" 5	12·7	4	168	21	4	261	24
"	40–50	" 5	12·0	3	157	16	4	225	27
"	50–60	" 5	12·0	—	—	—	5	231	14
"	60–70	" 5	11·1	—	—	—	2	208	4
"	70–80	" 5	12·8	3	147	—	3	207	13
"	80–100	" 5	12·9	—	—	—	4	216	21
"	100–120	" 5	13·2	—	—	—	1	231	—
"	120–140	" 5	13·3	—	—	—	1	234	—
"	Passed 140	" ·5	18·5	4	155	17	4	229	23

TABLE No. 23.—RED SANDSTONE.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	20–30	Mar. 29	13·0	3	142	9	3	279	6
"	30–40	" 29	12·4	3	121	2	3	200	12
"	40–50	" 29	12·3	2	145	7	3	226	17
"	50–60	" 29	11·9	3	130	19	4	218	26
"	60–70	" 29	11·8	3	130	7	3	208	23
"	70–80	" 29	12·5	4	120	14	4	202	25
"	80–100	" 29	13·3	3	117	21	4	194	19
"	100–120	" 29	14·0	3	131	8	4	191	14
"	120–140	" 29	16·1	2	124	2	1	211	—
"	Passed 140	" 29	15·8	2	151	4	4	218	12

TABLE No. 24.—EQUAL PARTS SAND AND CEMENT, BY MEASURE, WATER COMPUTED BY WEIGHT, AS BEFORE.

CEMENT.	Kind of Sand.	Size of Sand.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
					No. of Tests.	Mean Strain.	Greatest Dif. from Mean.	No. of Tests.	Mean Strain.	Greatest Dif. from Mean.
Brooklyn Bridge .	Florida Lime	8–12	Apr. 12	15·2	4	39	4	3	124	11
" " .	Trap Rock	8–12	" 12	13·5	3	57	4	4	195	11
" " .	Cockspur Beach . . .	All	" 12	15·4	4	16	1	4	53	6
" " .	Tybee Beach, No. 2 .	20–30	" 12	13·2	4	28	3	4	83	9
Dyckerhoff	Cockspur Beach . . .	All	" 25	12·5	—	—	—	9	177	14
"	River Sand	"	" 25	11·3	—	—	—	9	218	24
*Hoffman	Cockspur Beach . . .	"	Sept. 22	15·0	4	64	—	—	—	—
"	River Sand	"	" 22	16·2	4	64	—		*32 days*	
Dyckerhoff	"	"	May 11	10·9	4	122	11	5	173	11
"	Cockspur Beach . . .	"	" 11	12·9	4	112	4	5	147	24
Hoffman	" " . . .	"	" 12	—	—	—	—	16	88	21
"	River Sand	"	" 12	—	—	—	—	16	101	22

* Made in 1894, and were hand-tamped, all quantities by measure including water.

TABLE No. 25.—GIVING TESTS WITH A GREATER RATIO THAN 1 TO 1 OF SAND.

CEMENT.	SAND. Kind.	SAND. Grade.	Parts to 1 of Cement	Date Mixed.	Per Cent. Water.	7 DAYS No. of Tests	7 DAYS Mean Strain.	7 DAYS Greatest Dif. from Mean.	56 DAYS. No. of Tests	56 DAYS. Mean Strain.	56 DAYS. Greatest Dif. from Mean.
:kerhoff	River sand	All	2	Mar. 13	9·3	4	100	4	5	135	8
"	"	30–40	2	" 18	12·1	4	82	16	3	123	5
nt	"	30–40	2	" 18	11·4	4	76	10	4	127	17
:kerhoff	Cockspur Beach .	All	2	" 13	10·3	3	75	2	5	126	16
"	" " .	Held by 100	2	" 15	15·1	4	69	8	4	128	7
"	" " .	All	3	Apr. 25	12·5	—	—	—	10	98	12
"	River sand	"	3	" 25	10·4	—	—	—	10	100	13

TABLE No. 26.—SHOWING RELATIVE ACCURACY OF DIFFERENT EXPERIMENTERS.

NAME OF EXPERIMENTER.	Cement Used.	Parts of Sand to 1 of Cement	TESTS. Age.	TESTS. No. of Sets.	TESTS. No. in Each Set.	DIFFERENCE FROM MEAN. Greatest.	DIFFERENCE FROM MEAN. Mean.	Per Cent. of Mean Dif. with Mean Strain.
Goddard and Ewans . .	Natural	1	7	1	10	13	13	101
" " . .	"	1	56	1	10	20	20	19
" " . .	Portland	3	7	1	10	28	28	44
" " . .	"	3	56	1	10	29	29	17
Abbott and Morrison .	"	1	7	2	7	48	27	12
" " .	"	1	60	2	7	44	42	15
" "	Natural	1	7	1	8	11	11	25
" " .	"	1	60	1	8	4	4	5
Col. Poe	Portland	1	7	1	5	19	19	6
"	"	1	28	1	10	17	17	4
"	"	1	3 mo.	1	5	19	19	3
"	"	1½	7	1	10	29	29	6
"	"	1½	28	1	10	87	87	15
"	"	1½	3 mo.	1	10	76	76	10
"	"	2	3 mo.	5	5	57	35	6
"	"	3	7	1	5	9	9	6
"	"	3	28	8	5	32	16	6
"	Natural	2	28	3	7	17	12	6
"	"	2	3 mo.	10	5	36	25	8
"	"	1	7	3	5	24	14	16
"	"	1	28	3	5	68	34	14
"	"	1	3 mo.	2	5	54	37	9
A. S. Cooper	"	1	7	122	4	13	3½	9
"	"	1	56	135	4	34	10	10
"	Portland	1	7	82	4	28	11	7
"	"	1	56	104	4	60	16	7
"	"	2	7	5	4	16	8	10
"	"	2	56	5	4	17	11	8

RECENT ADVANCES IN BACTERIOLOGY WITH SPECIAL REFERENCE TO FOOD.*

By M. V. Ball, M.D.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Bacteriology is, comparatively, a recent science. Only within the last ten years has it received any special attention, and within this time it has been given a place in the medical colleges and become recognised as an important department of knowledge.

Municipalties are forming laboratories for bacteriological work, and governments are instituting, on a large scale, researches, which must eventually be of great service to mankind. It is hardly to be expected that this subject should as yet be the common property of any but those who have made it a special study, and, therefore, a few words as to the nature of bacteria will not be out of place here.

Bacteria—from the Greek, meaning little or minute *rods*—is a term applied to various forms of organisms, microscopic in size, closely allied to the lower types of fungi and algæ; usually containing no chlorophyll; capable, in many instances, of propelling themselves with swift motion through the liquids in which they are found, and possessing, for this purpose, small cilia or flagella, like other types of microscopic plants.

They are very minute, requiring for their detection powerful lenses. Some idea of their size may be obtained from the statement that in the space of an inch from 15,000 to 20,000 can be placed side by side; but, growing together in large numbers as they do, such aggregations or colonies can readily be seen with the unaided eye, though the individual members of these colonies cannot be recognised.

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*A lecture delivered before the Franklin Institute.

Bacteria are neither yeasts nor moulds, though possessing some of the characters of both.

The name, "bacteria," is not a good one, since other than rod-shaped organisms are collected under this group. Micrococci are globular or spherical bacteria; bacilli are the rod-shaped bacteria; and spirilli are spiral-formed or twisted bacteria. The colonies of one form are not to be distinguished from the others, but under the microscope the difference in shape is readily made out.

Bacteria are quick breeders; they multiply very rapidly. From one or two germs thousands are obtained in the course of a few hours. Some one has made the calculation that a single germ, if uninterrupted in its growth, would fill an ocean with its progeny in five days; but, fortunately, it digs its own grave by the poisons it generates, and so puts a limit to its growth. Some require several days before germination occurs. Two kinds of growth are known: one, in which reproduction is a process of fission or segmentation —one bacterium dividing itself into two, and each of these again sub-dividing—in reality, a continuation rather than a reproduction. And a second kind, known as sporulation. The germ gives rise to a spore, the spore then takes on a separate existence and, when the conditions favorable to maturation exist, it gives rise to a new germ.

Both forms of growth are utilised by the same bacterium. Under ordinary conditions it multiplies by fission when a permanent form is advantageous, or, as some think, when the soil is particularly rich, it produces spores. Spores have not been found in all bacteria; those possessing them are very resistant to all physical and chemical agencies, and withstand a high degree of heat without being destroyed.

For the different bacteria different conditions are necessary. Just as different plants require different kinds of soil and temperature, so these minute plants react differently and demand for their growth various surroundings. Some are not at all particular, and flourish on any sort of soil. They are like weeds that grow without attention; others again are as sensitive as hot-house plants, and require very carefully prepared media and a suitably regulated tempera-

ture. While some species demand a plentiful supply of oxygen, others grow only when this is excluded. Sunlight is usually destructive; an alkaline medium is better tolerated, than a neutral one, and acids are usually harmful. Moisture is necessary to growth.

Bacteria are not only disease-producers, they manufacture a host of products beneficial and essential to life. Life itself depends, in a great measure, upon the actions of these minute plants, which transform the complex molecules into their elements and make them fit for assimilation. If we could separate the industrial germs from the pathogenic or disease-producers, and domesticate the former, while we drive the latter out of existence, life would be more worth the living. This is gradually being attempted. Scientists are pointing out to us the properties of individual varieties, and showing us the methods of cultivation; while hygienists and therapeutists are doing all they can to exterminate the destroyers of life; so that we can already see how, in a few years, cholera will be a rare disease, and tuberculosis will no more be counted as the cause of one-fifth of all deaths.

What advances, if any, have been made in recent years as relates to the subject of *foods?* This is the topic I have been asked to consider: "Bacteria in their relation to food?"

First of all, I desire to take up the most important of foods, namely, *water*. Water is a food because it is necessary to sustain life, and considered in this sense air might also be classed as a food. But whether or not we call water a food, there are other reasons sufficient for us to make it a matter for consideration here.

Formerly a good water was one which came up to a certain chemical standard. The amount of chlorides and nitrates was determined, the hardness was computed and the total amount of solids ascertained. If a water did not contain more than 1 grain of chlorine per gallon, it was deemed potable. To-day, while chemical analysis still has an important place in the examination of water, it must go hand-in-hand with the biological or bacteriological analysis,

and we must know what sort of living organisms inhabit or are to be found in the specimen in question.

In the early days of bacteriology much stress was laid upon the number of bacteria found in a given quantity of water, and water containing more than 500 colonies to the cubic centimeter was deemed unfit for drinking, but now it is not so much the quantity as the quality of the bacteria that is looked for. One typhoid bacillus in a gallon of water is more dangerous than one million ordinary water bacteria; in fact, it would render the water impotable, while the latter would be harmless. Thus, the water analyst of to-day must be a competent bacteriologist as well as chemist; and to be a bacteriologist means a pathologist as well, for, in the investigation of bacteria, animals must be used for experiment, and the nature of the diseases caused by the bacteria must be known to the experimenter.

As in the earlier chemical analyses, the chlorine itself was not considered dangerous, but simply one of the indications of fæcal contamination, so in the bacterial examination, the presence of certain harmless germs may indicate dangerous contaminations. For instance, the presence of the bacilli commonly found in human fæces, which in themselves are non-pathogenic, would, of course, lead one to infer that human sewage had become mixed with the water supply.

The methods for the detection of typhoid bacilli in drinking-water leave much to be desired. The examination is often undertaken too late, when the bacilli are no longer present, or have been destroyed by the ordinary water bacteria. Typhoid bacilli do not live long in ordinary drinking-water; and yet, if the water be contaminated with them, a whole city or district can become infected in a short time, and when suspicion is directed to the water the germs have disappeared. To a less degree, this is likewise true of the cholera spirillum, which acts so quickly and is so deadly, and which usually is spread through the drinking-water.

A method lately described, and which promises success, is to take a large quantity of the suspected water (200 cubic centimeters), and add to it 2 grams of peptone and 2 grams of

chloride of sodium. Place this in the incubating oven, and, if cholera germs are present, they will multiply rapidly, so that they can readily be detected in the course of ten to twelve hours.

Bacteric examinations have been most useful in the testing of water filters, "germ-proof" filters, etc. Several filters are now in the market, which claim to be germ-proof; that is to say, which are supposed to prevent the passage of bacteria through the very minute pores of the filter. These filters are made of baked clay, infusorial earth, porcelain, etc. As a rule, they can deliver a germless water only for a few days in succession, when, owing to the activity of the bacteria which have collected on the surface of the filter cylinder, the pores are penetrated by the growth, and more bacteria than usual find their way into the water. This, in some cases, can be prevented by a careful cleansing, every few days, of the filter tube. All tubes are not alike, and some afford no protection at all, though they clarify the water by keeping out the grosser particles of dirt.

Filters are best tested by adding to the water, before filtration, some well-known bacterium (usually the red pigment-forming and rapid-growing *Bacillus prodigiosus*) making cultures before and then after filtration. If, under suitable precautions, the germ is found present in the filtered water, the filter is imperfect. In the testing of large filtering plants, where it is not expected that the water will be perfectly free from germs, quantitative methods must be used, in order to tell what percentage of bacteria is left behind.

These large filtering plants are in use in several cities, and, it seems to me, they are of doubtful value only. It is true, the water is more pleasing to the eye, and, for toilet and laundry purposes, more valuable; but if the water is contaminated with disease germs there is no surety that they will be among the 50 per cent. filtered out. They are just as liable to pass through as the others, and such a water is not safe. From the sanitary point of view, filtering plants are only valuable when the water is uncontaminated by human sewage; and to erect such a plant in our city, without paying any attention to the source of our water

supply, and even allowing it to be polluted along its whole course, will hardly reduce the death rate, though it may add to the æsthetic quality of the water.

On an average, 500 deaths occur every year in this city from typhoid fever. This means at least 6,000 cases. From an economic point of view, the persons affected are the most valuable members of society, chiefly young adults between the ages of 20 and 40. The expense, in loss of time, medical attendance, etc., is at least $100 for each case, a total cost of $600,000 yearly from this one disease, to say nothing about the loss of life; and all because we are obliged to drink the sewage of half a dozen towns above us, and the drainings from graveyards and pigsties along the banks of the Schuylkill.

And while we are thus treated by the cities above us, we send our sewage to the towns below. Some strict measures must be put into practice, which will prevent this pollution of our drinking-water.

The second important article of food, with which bacteriologists have busied themselves, is *milk*. A good milk must contain a certain amount of solids and fat, but it can be adulterated with far more harmful matters than water, and these other adulterations are not so readily detected.

A few hours after milking, ordinary milk has been found to contain 1,000,000 germs to the cubic centimeter. How did these get in?

If the udders of the cow are not kept clean, the first flow of milk will wash the dirt into the milking-pan. If the man who milks the cow is uncleanly in his habits, using dirty hands in the operation, the milk receives this dirt. If the stall is the place for milking, and other animals are moving about, the dust raised falls into the open pail and contaminates the fluid; and, finally, in the transportation from the farmer to the collector, from the dealer to the customer, a hundred opportunities present themselves for the entrance of bacteria, which, when once in, thrive abundantly, the milk being a rich and suitable soil for their growth.

In the markets of Halle, Berlin and Leipsic, Ranke succeeded in finding, in the milk exposed for sale, considerable

quantities of cow-dung, which, of course,greatly increased the number of germs to the cubic centimeter—in one case up to 169,000,000.

Bolle, the milkman of Berlin, who sells 60,000 quarts of milk daily, has endeavored to make his large establishment conform to scientific requirements. He has a competent bacteriologist, who makes frequent examinations of the product. The milk is obtained from such dairies only as are under his inspection. Separate examinations are made of the different herds, so as to trace disease to its proper source. The collected milk is filtered each day through immense sieves of gravel, which have first been subjected to a high degree of heat in order to sterilise them. The milk is forced through from below upwards, and collected in proper vessels. Four thousand quarts pass through such a filter in one hour. By this means the dirt is removed and with it about 50 per cent. of the bacteria present.

While this filtered milk keeps longer than the unfiltered, and is more readily sterilised, it is just as dangerous if disease germs were originally present, since, as was stated above, in connection with the filtration of water, the disease germs are just as likely to be among the 50 per cent. that pass through as to be among those that remain.

In order to render milk completely sterile, it must be subjected to such a degree of heat as will coagulate the casein and make the product undesirable in other ways. If, however, great care be exercised in the milking, and sterilisation be carried on at once or shortly after, a very moderate degree of heat will be sufficient to make the milk entirely sterile.

One of the bacteria that is often found in milk has very resistant spores, and, therefore, if milk becomes contaminated by exposure to the dust and dirt of the air or stall, ordinary warming or heating, as is done when milk is Pasteurised (so-called sterilised milk), will not suffice to destroy these spores.

Milk is often sold to us in bottles, and one would imagine that such a product was reasonably clean; but this bottling is done in a very careless way, often in the street by some

ignorant delivery boy, while the street sweeper is raising clouds of dust, some of which lodges in the exposed milk.

In one dairy in Dresden, Germany, all the milk comes from stall-fed, or dry-fed, cows, experience having shown that such cows give a product that is less variable, and contains fewer germs, and sours less speedily than when they are fed on fresh grass. Great care is taken in the milking, and especial attention is paid to the cleanliness of the employés. After the milking, the milk is placed in coolers, where it remains two hours, at a temperature of 10° C. Then it is put into a centrifuge, in order to separate the dirt that might accidentally have fallen in. It is now warmed up to 65° C. (Pasteurised), and collected in half-pint sterilised bottles, and the filled bottles again heated for one hour and three-quarters, at 65° C., and quickly cooled. Such milk is reasonably sterile, and the method is the only one to be recommended.

Unless all these steps are followed the milk cannot be considered sterile.

What danger is there in milk from tuberculous cows? This is a question which, just at present, is receiving considable attention.

Tuberculosis is very frequent among cattle. In the slaughter-houses of Berlin, out of 142,000 head of cattle, 21,000, or 15 per cent., were found to be tubercular. In all Prussia 10 per cent. of all the cattle slaughtered annually are found to be affected with this disease. Some veterinarians claim that 30 per cent. of all cows are infected, and that a herd cannot be found that is entirely free from the disease. From this, one can readily see the importance of this question. In New York City 900,000 quarts of milk are consumed daily. Consumption is likewise a very common disease, causing from one-third to one-fourth of all the deaths among adults, and many, if not the greater number of the diseases of children are tubercular in origin.

Is the cow an enemy to man? Are we warranted in accusing the milk of consumptive cows as being the cause of consumption in man? The last word has not yet been said on this subject. We can only give the opinions of authori-

ties, the present beliefs gained from the knowledge at hand; and these are that, if the udders of a cow are unaffected, if there is no local tuberculosis, no bacilli are to be found in the milk, the milk may be considered safe. Yet, later investigations have shown that the toxic principles of bacteria find their way into the milk, that the milk of an animal rendered immune to diphtheria or tetanus has the same properties as the serum of the blood, and can protect other animals. If this is uncontroverted, then the milk of tuberculous or consumptive cows may have within it the products of the tubercle bacilli, and such milk may have the same effect upon the human organism as these products obtained artificially, or from cultures outside of the body. The discussion on the benefits or ill effects of *tuberculin* has not yet been closed, and it is impossible to say, therefore, whether such milk, *i. e.*, milk containing tuberculin, is positively harmless or dangerous.

In Paris all cows whose milk is offered for sale must be tested with tuberculin to prove their freedom from tuberculosis. Our own Board of Health has strongly advocated a similar test.

Tuberculin has been found reliable in the greater number of cases; *i. e.*, if an animal showed signs of temperature rise after the injection of the tuberculin, the disease has always been found present; but the disease has been found when no rise has occurred, so that it is a positive test only. Tuberculosis is present whenever there is a rise of temperature, but it is not necessarily absent if no reaction occurs.

Because tuberculosis is so very frequent, because 2,700 deaths of adults between 15 and 45 occur every year in this city alone from this one disease, it behooves us to try every measure that holds out the slightest chance of success in reducing this awful mortality, and, therefore, if only as an experiment, it would be worth the time and money to destroy every suspicious animal, and thus prevent the sale of all milk save that obtained from perfectly sound cows. Any reduction in the death rate from this disease will be a step in advance, and our efforts should be directed to this end at all cost.

If the milk of consumptive cows is dangerous, then cheese and butter made from such milk is likewise dangerous, and the sale of such should be equally guarded against.

In Germany, butter has been made from sterilised milk by the addition of pure cultures of certain bacteria, which have the power of coagulating the milk. Such butter has a constant flavor, and does not deteriorate so quickly as butter produced in the ordinary way.

To summarise in regard to milk, we can say that (1) a careful inspection of the dairy; (2) a close examination of the cattle; and (3) cleanliness in the transportation and sale, must be rigorously enforced to safeguard the public health.

As regards meat, little has been said or done. Meat is rarely used in the raw state, and cooking generally renders ineffective the germs likely to be found present.

In the cities of Europe, careful inspection is practiced at the abattoirs, and meat from diseased cattle is excluded or sold under restrictions. Meat-shops are likewise kept very clean, and the meat is seldom exposed in filthy warehouses. In our own cities some of the meat offered for sale on the stands and in street shops is most unfit for food,—some of it, indeed, in a state of putrefaction. Some cities have laws which make such meat liable to seizure, but these laws are seldom operative.

The advances in fermentation deserve attention, for, though they are not, strictly speaking, connected with our subject, yet so closely are the yeasts related to bacteria, and so similar are the methods of cultivation, that any discoveries in the one field are sure to be of value in the other. Bacteria have always been a disturbing element in industrial fermentations, and expensive methods have been resorted to, to prevent the entrance of disease germs—disease, here, meaning impure or improper germs.

The yeasts were formerly considered as few in number—as alcohol-producers and non-alcohol-producers—no serious efforts were made to obtain pure cultures, but the mashes and brews were kept under such conditions that the foreign germs were prevented from growing or multiplying. Beer

was stored in ice-cellars, whiskey was subjected to special temperatures, and other elaborate measures were used which now can be dispensed with if we start with pure cultures of yeasts at the beginning, and avoid the entrance of impurities from air, water, etc.

In Denmark, Hansen (and from him a school has originated) pays great attention to the cultivation of pure yeasts. Brewers can obtain from the laboratories such pure cultures and thereby insure a definite alcoholic strength, a constant flavor, and a product that will not deteriorate, even under varying conditions of temperature, etc.

By experimenting with different combinations of yeasts, various degrees of bitterness and different aromas can be developed.

Wines depend very largely for their bouquet, not so much upon the grape as upon the particular germ or germs used in the fermentation of the juice. Experimenters have obtained, with the same kind of grape, a half-dozen different wines by using as many different yeasts. As the pigment yeasts produce various colors, so the yeasts used in fermentation give rise to various ethers, and these ethers give the wine its peculiar bouquet.

We should expect to obtain a Rhine wine from a New Jersey grape by using the yeasts which are common in the Rhine region, or on the Rhine grape. Even out of apple most, a good-tasting wine has been produced by the use of particular cultures of yeast.

These researches have revolutionised German brewing, and the large breweries now have competent bacteriologists in their employ, who attend to the cultivation of their yeasts.

The spaces or holes peculiar to certain *cheeses* are due to the evolution of gases during the ripening process. These gases are produced by certain bacteria, and by using pure cultures of these gas-forming bacteria in the manufacture of cheese, these air-spaces will always occur. The odor of cheese is likewise due to bacteria, and special flavors can thus be obtained at will by using the particular germs.

Bread made from pure yeast will be found to be more

digestible, to be lighter and to posséss a sweeter flavor. Too little attention has been paid to this in baking. Mixtures of yeasts and bacteria are used, and the baking powder or the flour is blamed for poor results. Sour bread is usually due to a poor quality or impure kind of yeast. The soil out of which we obtain such important food-stuffs has been studied bacterially and has been found to contain peculiar germs, which are all necessary to the growth of the plant. These are the so-called nitrogen-forming bacteria.

They convert the nitrates into nitrites, the oxidisers of organic material, more necessary to the well-being of vegetable life than anything else. Instead of using tons of fertilisers, the agriculturist of the future will cover his fields with cultures of the nitrogen germs and obtain better results. We will even have special germs for special plants. The science of agriculture is yet in its infancy, if we may believe the promises held out to it by bacteriology. Even at present the agricultural colleges are equipping themselves with laboratories for bacteriological research.

Thus I have tried to show that the recent advances in this science are as nothing compared with what may yet be expected; that in these germs, microbes and bacteria, mankind has deadly foes and also important friends; that we must do all we can to rid ourselves of the former and make the latter our willing slaves.

ALUMINIUM SOLDERS.*

BY JOSEPH RICHARDS.

Very soon after Deville first made aluminium on a large scale, it was found that it was a most difficult problem to solder it satisfactorily. The ordinary alloys used for soldering were found not to attach themselves to aluminium, despite every usual precaution, and it was seen that unusual solders must be devised to meet this unusual problem. M. Christofle, the goldsmith, of Paris, gave the subject

*Abstract of remarks made before the Institute.

his special attention, and discovered that aluminium was wetted by, and could therefore be soldered with, either pure zinc or pure tin. It is indeed true that both these metals hold firmly to the aluminium, but the zinc seam is brittle and crystalline, will not stand working, and discolors badly in a short time, while the tin seam has the disadvantage of disintegrating and falling to pieces in a few weeks. This latter phenomenon is due to the fact that certain alloys of tin and aluminium will decompose spontaneously by the action of the air. This is particularly true of tin containing small proportions of aluminium, up to 10 per cent.; for, if a bar of such alloy is left in the air, and portions are broken off at regular intervals, a change will be visible in the section, proceeding from the outside towards the center; and while at first the alloy is strong and tough, it gradually becomes more and more friable until, at length, when the change has reached the center, it breaks like a pipe-stem. I have observed a bar, $\frac{1}{16}$ inch thick, to become decomposed all through in three weeks, and on thinner sections the effect is still more marked. Tin containing 0·5 per cent. of aluminium was rolled by a Philadelphia maker of tin-foil into foil, 0·001 inch thick, and, while it rolled beautifully, yet in two hours thereafter the whole sheet was as brittle as glass. Now, bearing these facts in mind, it can easily be understood why a joint soldered with tin falls apart. The tin attaches itself to the aluminium by forming an alloy at the junction, and this alloy decomposes in a short time.

It would be a serious task to catalogue all the different metallic mixtures which have been proposed for soldering aluminium since M. Christofle's experiments in 1855. Alloys of aluminium and zinc were tried by the Tissier Bros., but were found to be too brittle. M. Hulot proposed to first plate the aluminium at the joint with copper, and to solder the coppered surfaces with ordinary solder.

At length, the Société d' Encouragement offered a prize for a solution of this problem, which was awarded to Mourey, a Parisian goldsmith. His best solders were alloys of aluminium and zinc, to which small proportions of copper were added, to give them toughness. The chief difficulty

with these solders is their high melting-point; the zinc, which melts only at incipient red heat, being the most easily fusible ingredient.

For brazing and blow-pipe work, such high-melting alloys can be used, and the addition of a little silver improves them still more; but none of them can be regarded as convenient for use with the soldering-iron.

It has been claimed that by using silver chloride as a flux, aluminium can be soldered in the ordinary way with ordinary tin solder; but this method has not proved satisfactory in practice, and, even if it were, the flux is too expensive.

Starting with a full understanding of the difficulties of the problem, and a knowledge of what had been previously tried and found wanting, I proceeded with the object of finding, if possible, a solder which should have the following qualifications:

(1) It must wet the aluminium and adhere firmly:

(2) It must not disintegrate after exposure to the air:

(3) It must be as malleable and strong as aluminium:

(4) It must have a low melting-point, so as to be easily worked with a soldering-iron:

(5) It must have the same color as aluminium, and not change color; and

(6) It must be cheap enough for general use.

After experimenting about two years, it was finally found that an alloy of zinc and tin in certain proportions, containing a little aluminium and some *phosphorus*, realised almost every qualification. The alloy used for some time was made by fusing together:

	Parts.
Aluminium	1
Ten per cent. phosphor-tin	1
Zinc	8
Tin	32

It was found, however, that, on re-melting this solder, a more fusible alloy liquated away from it. It appeared reasonable to assume that this more fusible part was a true alloy of zinc and tin, and, therefore, a more stable compound. This fusible portion was also found to solder better

than the original mixture. This liquated solder was therefore analysed, with the result that its composition was found to be very close to that expressed by the formula Sn_4Zn_3. The solder which I now use is made to correspond closely to this formula. It is obtained by using the ingredients in the proportions 1, 1, 11, 29, instead of 1, 1, 8, 32, as previously described. The percentage composition of the several alloys described may be thus compared:

	Original Solder.	Found in the Liquated Alloy.	The Formula Sn_4Zn_3 Calls for	Solder, as now Made, Contains	
Aluminium . .	2·38	—	—	2·38	Zinc + Aluminium, 28·57 per cent.
Zinc	19·04	—	29·3	26·19	
Tin	78·34	71·65	70·7	71·19	
Phosphorus . .	0·24	—	—	0·24	

The percentage of zinc in the new solder is lower than called for by the formula Sn_4Zn_3; but since aluminium and zinc are metals having many physical analogies, it was thought advisable to bring the combined percentage of these up to that required for the zinc alone. Further, as the tin is most liable to lose by oxidation during the mixing of the solder, it was thought best to have it slightly in excess.

The result of these investigations is before you in the specimens of soldering presented for your inspection. As practical usefulness is a fair criterion of the value of an invention, I may be permitted to mention that this solder has come largely into use in Germany, Switzerland, England and our own country.

It must be remembered that at present the demand for an aluminium solder is limited. About 4 tons of aluminium are now produced daily in the world, but fully 75 per cent. of this is used up in the steel industry and in making alloys; while, of the remaining 25 per cent., which is rolled, spun, cast, or stamped into pure aluminium articles, probably not 10 per cent. is in such shape as to require soldering. Assuming, then, an average of 200 pounds a day of aluminium

articles to be soldered, a daily supply of a very few pounds of solder would meet the entire demand.

It does not require the prophetic eye, however, to see that the 1,000 tons of aluminium produced during 1893 will probably reach 10,000 tons a year within the next ten years, and that with increased production the demand for a good solder must correspondingly increase.

In conclusion, I wish to add that I am indebted to my son, Dr. J. W. Richards, of Lehigh University, for chemical analyses and other aid in preparing this solder.

On the GROWTH and SUSTAINING POWER of ICE.

By P. Vedel, C. E., M. West. Soc. Eng.

When, in the fall, the temperature of the air decreases, the water gets gradually cooled off from the surface. The colder surface water sinks down and the warmer water from below rises, gets cooled off at the surface and sinks again to let some relatively warmer water from below rise in its turn, and so on continually, as long as the colder water has a greater specific gravity than the warmer. So far, this process of cooling off from the upper surface is parallel to the heating of the water in a boiler by a similar circulation from the under surface. But it is known that water, unlike any other fluid, has its maximum density at a certain temperature, and expands from that point whether the temperature decreases or increases. For pure, fresh water, the specific gravity increases from 1 at 62° F., to its maximum 1·00112 at 39°·2 F. (4° C.); for sea water, the corresponding temperature is $25\frac{2}{3}$°–27° F. When, therefore, the surface water is cooled off to 39°·2 F., it sinks, not to rise again unless either heat or cold is conveyed to it at the bottom. The water which has taken its place at the surface sinks, to remain below at that same temperature, and, consequently, when the whole water body is cooled down to 39°·2 F., all circula-

tion stops. The only way in which the water can then be further cooled off from the surface is by conduction, but the conductivity of water being small, this is a very slow process compared with the former.

When the temperature of the surface-layer reaches 32° F., ice is generally formed in fresh water; the freezing point of sea water is at 27°–28° F. But rapid running streams may not be ice-bound at much lower temperatures, and in perfectly calm water the temperature may go down considerably, perhaps 10°–12° below the freezing point, before the formation of ice, which then takes place suddenly by the slightest motion, caused, for instance, by a gust of wind or the introduction of an ice crystal. The heat of liquefaction, being set free, raises the temperature of the ice to 32° F., but, immediately after, its upper surface partakes of the variations of the temperature of the air. The ice cover protects the water from agitation by winds and from further cooling, inasmuch as the heat from the water now has to be conveyed the greater distance, through ice and through snow, which may have fallen upon it.

But the bottom of a lake or a river, if not too shallow, has a temperature corresponding to that of the earth crust at the same depth. At 6½ feet below the surface the annual mean temperature of the soil was 55° F., when that of the air was 50°·4 F., and the extreme variations were respectively 24°·7 and 84° F. At 50–60 feet depth the temperature is approximately uniform, 50°–60° F. in temperate climates, and increasing about 1° F. for each additional 50–60 feet. But at less depth the temperature will change with the seasons, only so slowly that maximum below may be reached several months after the summer above. The bottom will then give off heat to the water nearest to it and currents may arise. Thus, the temperature may be 33° directly under the ice, 39° about 6 feet below, and 42° F. at the bottom, 25 feet below the surface. On the other hand, the average temperature of the water beneath the ice is sometimes found less than 39°·2, although the cold has not lasted long enough to have produced it by conduction only; thus, in some of the Scot-

tish lochs, temperatures of 34°–37°–38° F. have been measured. An explanation* of this phenomenon is sought in differences in temperature of the air on different points of the lake. An ice-fringe first being formed near shore, currents are produced by the different densities of the water under the ice and outside it, a surface current carrying water from shore towards the center of the lake, where it is cooled off by the air, and undercurrents carrying it back towards shore. Also, at the bottom of open, running water, especially on shoals, the temperature may sink to, or—perhaps by radiation—below, that at the surface, and give rise to the formation of anchor or ground ice ("groundgru," "frozee"), the current at the bottom being retarded by the friction.

The specific gravity of ice lies between 0·90 and 0·95, and may as an average be taken as 0·92. In freezing, water therefore increases in volume from $\frac{1}{9}$ to $\frac{1}{18}$, or as an average $\frac{1}{11}$; and, when floating, the ice will be immersed about $\frac{11}{12}$, while $\frac{1}{12}$ of its mass will be above water. The formation of ice is, perhaps, rather an intermittent than a continuous process; but it seems to be proved that the growth always is downwards, due to the freezing of the water under the ice, and not of vapors condensed on its upper surface. Still, such vapors escaping through or from the ice, or the so-called "frost smoke," may produce those beautiful hexagonal stellate crystals, or six-leaved ice flowers, which in cold weather are sometimes found on its surface. And when by a rise of the river the ice-sheet is held down by its sides, and thus, or by rain or melting snow, or in any other way, its surface becomes covered with water, then a subsequent frost will, of course, increase its thickness by a growth upwards. But such growth, being accidental and due to particular, incalculable circumstances, may here be left out of consideration.

The rate at which the ice is formed and grows depends upon the temperature of the air and the condition of the water, whether still or running, in a rock- or mud-bed, with

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* *Nature*, 1879.

or without springs in the bottom, salt or fresh, pure, or polluted with organic, putrescent matter. The specific gravities of ice and water, specific and latent heats, coefficients of conduction and radiation, etc., all influence the formation of ice.

Let D be depth of water under the ice, H the thickness of the ice-sheet, $d\,H$ its increase in the time $d\,\tau$, the corresponding decrease of D being less than $d\,H$ on account of the expansion in freezing; the temperature of the air be T, of the upper surface of the ice t, of its under surface as of the upper layer of the water that of the freezing point, and at the bottom that of maximum density.* For simplicity's sake all dimensions are expressed in meters, an area of one square meter of the ice-sheet being considered, and all temperatures in Centigrade. Before the increase $d\,H$ took place the water contained

$$\frac{0+4}{2} s_w\, \delta_w\, D + l_w\, \delta_w\, D$$

heat units, and the ice

$$\frac{0+t}{2} s_i\, \delta_i\, H \text{ h. u.}$$

in which s_w and s_i are, respectively, the specific heats of water and ice, both supposed to be constant, δ_w and δ_i their respective specific gravities, corresponding to the average temperatures

$$\frac{0+4}{2} \text{ and } \frac{0+t}{2}$$

and l_w the latent heat of water. After the formation of the layer $d\,H$ the water and ice together contain:

$$\frac{0+4}{2} s_w\, \delta_w \left(D - \frac{\delta_i}{\delta_w}\, d\,H\right) + l_w\, \delta_w \left(D - \frac{\delta_i}{\delta_w}\, d\,H\right)$$
$$+ \frac{0+t}{2} s_i\, \delta_i\, (H + d\,H) \text{ h. u.}$$

* This is only approximately correct. It lies between that temperature and the freezing point. But the influence upon the result is unimportant. The temperature of the under side of the ice is, perhaps, also different from that of the water.

Hence the whole system has lost:

$$2\, s_w\, \delta_i\, d\, H + l_w\, \delta_i\, d\, H - \frac{t}{2}\, s_i\, \delta_i\, d\, H \text{ h. u.} \tag{1}$$

By conduction there passes in the time $d\,\tau$ through the ice $C\,(0 - t)\,d\,\tau$ or:

$$- C\, t\, d\, \tau \text{ h. u.} \tag{2}$$

where:

$$\frac{1}{C} = \frac{1}{\frac{a}{t - T}} + \frac{H}{c_i} = \frac{t - T}{a} + \frac{H}{c_i}$$

where a is the number of heat units conveyed by radiation to the air or by convection with it, and c_i is the coefficient of conduction of the ice, both per hour.

Now, (2) must be the same as $a\, d\, \tau$, and the same as (1). Hence:

$$a = - C\, t = - \frac{t}{\frac{t - T}{a} + \frac{H}{c_i}} \quad \therefore \quad a = \frac{c_i}{H}(T - 2\, t)$$

and:

$$(2\, s_w + l_w - \frac{t}{2}\, s_i)\, \delta_i\, d\, H = a\, d\, \tau = \frac{c_i}{H}\,(T - 2\, t)\, d\, \tau \tag{3}$$

To determine the temperature, t, we must find another expression for a. By radiation to the air, escapes per hour from the ice, according to Dulong and Petit:*

$$125\, r\, (1{\cdot}0077^t - 1{\cdot}0077^T) \text{ h. u.}$$

where r is the coefficient of radiation And, by convection, there is carried away by the air per hour:

$$0{\cdot}55\, b\, (t - T)^{1{\cdot}233} \text{ h. u.}$$

where b is the coefficient of contact. The total amount of heat units given off by the ice to the air is, therefore:

$$a = \frac{c_i}{H}(T - 2\, t) = 125\, r\, (1{\cdot}0077^t - 1{\cdot}0077^T) + 0{\cdot}55\, b\, (t - T)^{1{\cdot}233} \tag{4}$$

whence t.

* Hütte: "Ingenieurs Taschenbuch," Berlin, 1892.

The growth of the ice is thus given by equation (3), in connection with (4). Developing in the latter the exponential and binomial terms:

$$1{\cdot}0077^t = 1 + \frac{hyp.\ log.\ 1{\cdot}0077}{1}\, t + \ldots .$$

$$= 1 + 0{\cdot}01\, t + 0{\cdot}00005\, t^2 + \ldots .$$

$$\left(1 - \frac{t}{T}\right)^{1{\cdot}233} = 1 - \frac{1{\cdot}233}{1}\frac{t}{T} + \ldots .$$

$$= 1 - 1{\cdot}233\,\frac{t}{T} + 0{\cdot}144\left(\frac{t}{T}\right)^2 + \ldots .$$

we find, approximately:

$$\frac{t}{T} = \frac{1{\cdot}25\, r + 0{\cdot}55\, b\,(-T)^{0{\cdot}233} + \frac{c_i}{H}}{1{\cdot}25\, r + 0{\cdot}61\, b\,(-T)^{0{\cdot}233} + 2\frac{c_i}{H}}$$

which for $r = 5{\cdot}31$, $b = 5$, $c_i = 0{\cdot}0024$, H lying between 0·01 and 1, and T between 0 and $-50°$, varies from 0·93 to 1·00. Hence

$$t = 0{\cdot}95\ T \tag{5}$$

Returning now to equation (3), we may consider

$$\frac{t}{2}\, s_i$$

as constant, taking an average value for it. Hence, by integration:

$$\int_0^H \left(2\, s_w + l_w - \frac{t}{2}\, s_i\right) \delta_i\, H\, dH = \int_0^{24n} c_i\,(T' - 2\, t)\, d\tau \tag{6}$$

n being the number of days since the first formation of ice. And by (5):

$$\left(2\, s_w + l_w - \frac{t}{2}\, s_i\right) \delta_i\, \frac{H^2}{2} = 0{\cdot}9\, c_i \sum_0^{24n} (-T)$$

$$= 21{\cdot}6\, c_i \sum_0^{n} (-T)$$

T being the average temperature for 24 hours. Hence:

$$H^2 = \frac{43\, c_i \sum_0^n (-T)}{(2\, s_w + l_w - \frac{t}{2} s_i)\, \delta_i} \tag{7}$$

which determines the thickness of the ice by the sum of the daily mean temperatures. The physical constants of ice and water which enter into this expression are, approximately:

$s_w = 1{\cdot}0224$, $s_i = 0{\cdot}505$, $\delta_i = 0{\cdot}92$, $l_w = 79{\cdot}25$,

and, therefore:

$$H^2 = \frac{46{\cdot}7\, c_i \sum_0^n (-T)}{81{\cdot}3 - 0{\cdot}25\, t} \tag{7'}$$

or, approximately:

$$H^2 = \frac{46{\cdot}7}{83}\, c_i \sum_0^n (-T) = 0{\cdot}56\, c_i \sum_0^n (-T)$$

The coefficient c_i is, unfortunately, only imperfectly known. The heat-transmitting power of ice has been stated to be 0·06 times that of air, for which the coefficient of conduction is 0·04. This would make $c_i = 0{\cdot}0024$, as assumed above. But, taking the resistance to the passage of heat from the water to the ice into consideration, the coefficient should be taken somewhat less, or, say, $c_i = 0{\cdot}002$. This will make:

$$H^2 = 0{\cdot}00112 \sum_0^n (-T)$$

where H is expressed in meters, T in degrees Centigrade. Transforming to inches and degrees Fahrenheit, we deduce:

$$H^2 = 0{\cdot}96 \sum_0^n (32 - T) \tag{8}$$

For salt water, with the freezing point at 27° and temperature of maximum density at 26°, this expression will be altered to:

$$H^2 = 1{\cdot}02 \sum_0^n (27 - T) \tag{8'}$$

As there are always springs and currents in the water, convection of heat from the bottom and more or less snow on the surface of the ice, the rate of increase of thickness must necessarily fall short of the theoretical. Evaporation has also the same effect. This has not been taken into consideration, and, according to the Boston Water Works experiments, may amount to 0·06 inch per day. In the general formula:

$$H^2 = k \sum_{0}^{n}{}' (f - T) \qquad (9)$$

where f is the freezing temperature, 0° C. or 32° F. for fresh water, and — 2°·5 C. or 27°–28° F. for salt water, the coefficient k, the maximum of which, for inches and degrees Fahrenheit, is about 1, must always be considerably less than this.

In studying the growth of ice in the Arctic Sea, Dr. Stefan* deduced a formula which differs slightly from (7), to wit:

$$H^2 = \frac{2\, c_i \sum_{0}^{24n}{}' (-T)}{\left(l_w + \frac{t}{3} s_i\right) \delta_i}$$

or, as he writes it:

$$H^2 \left(1 + \frac{s_i\, t}{3\, l_w}\right) = \frac{2\, c_i}{l_w\, \delta_i} \sum_{0}^{24n}{}' (-T)$$

Observations from Arctic expeditions to nine different localities all agreed closely with formula (9), giving nearly constant values for k. With inch, Fahrenheit degree, and the day of twenty-four hours as units, its average value was:

$$k = 0{\cdot}87$$

with extreme values 0·70 and 0·92; with centimeter and Centigrade degree as units, it is:

$$k = 10{\cdot}09$$

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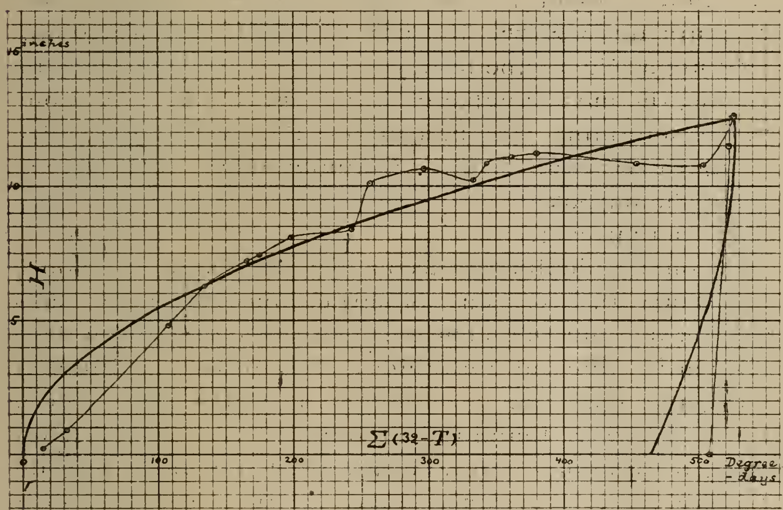
* *Nature*, **40**, 1889.

A series of careful observations were taken by the writer during the winter 1893-4 on a side branch of the Desplaines River, near Willow Springs, Ill., for a growth of ice from 0 to $12\frac{1}{2}$ inches. The river-bed consists of soft mud and fine shells to a varying but generally considerable depth, with numerous springs in the bottom. No currents could disturb the water in the side branch but those arising from a variation of the water level of some 2 or 3 feet. A heavy snowfall occurred once or twice, covering the ice until swept away by the wind. The coefficient k could, therefore, not be expected to come anywhere near its max-



imum, 0·96, but must be only a fraction thereof. By the method of least squares it is found to be:

$$k = 0{\cdot}30$$

The curve (see *Fig.*) plotted from the observed values of H and $\Sigma(32 - T)$ differs not more than could be expected from the parabola, the mean error on H being 0·8 inch.

On a lake, 15 inches of ice were formed* during twenty-one days of nearly uniform temperature, ranging from

* *Am. Journ. of Science and Arts*, **3**, 179.

— 7° to + 11° F. Taking, as an average, + 2° F. we find for the coefficient:

$$k = 0{\cdot}36$$

For the practical use of the formula (9) and for determining the coefficient k, it is necessary to keep an account of the daily mean temperatures. The use of a self-registering thermometer, or the taking of hourly readings day and night, will seldom be convenient and are altogether unnecessary. For it has been found* for temperate climates that in the winter months the daily mean temperature is the same as the temperature at 9 A.M. and at 7.30 P.M.; also that it is the same as the mean of the daily minimum and the daily maximum temperature, the first of which during the winter occurs at 6 A.M., the latter at 2 P.M. By taking readings, therefore, of the temperature at 6 A.M., 9 A.M., 2 P.M. and 7.30 P.M., the mean temperature for the twenty-four hours will be determined in three different ways. For the two readings a minimum- and a maximum-thermometer would answer the purpose.

The actual measurement of the thickness of the ice offers some difficulty on account of the spongy or honeycombed structure at its under surface and the frozen snow on top of it. But the coefficient k of the general formula (9) is evidently different for different localities and different waters, and must, therefore, be determined by direct observation. We have found its maximum value to be nearly 1, its actual value in an average case for fresh water 0·30, and for salt water in the Arctics 0·87, and often meet with cases of swift-running rivers or specially heated waters where it is 0 or approximately so. The corresponding relative values of H are 1, 0·55 and 0·93. In absence of any observations, sound judgment must assign a value to k.

When the temperature rises above the freezing point and thaw sets in, the ice thaws away from the upper surface or from the side exposed to the heat, and consequently will thaw much faster than it froze before. Continuing the curve (comp. *Fig.*) after the thaw, when $\triangle T$ is negative, it

Journ. Frank. Inst., **23** and **26**.

will fall faster than it rose, and finally will reach the T axis long before the sum of thawing temperatures equals the sum of freezing temperatures expended in the production of the ice. As the colder air, on account of its greater specific gravity, will remain near the surface of the ice, it will take some time, and the sum of temperatures of the air measured some distance above that level, will have reached a certain amount before the ice begins to thaw. From that time the relation between the decrease of the thickness of the ice, $H_1 - H$, and the sum of temperatures may, by a similar procedure as above, be found to be approximately that of the co-ordinates of a parabola.*

The sudden disappearance of the ice on various lakes has often caused surprise. On Lake Champlain an expanse of ice 12 inches thick has been known to vanish during a single night. It has been found in such cases that the ice was transformed from a solid homogeneous mass into an aggregation of irregular, prismatic needles, placed vertically, close together, and with but a trifling cohesion to one another. This is the "penknife-ice" which Captain Parry met with in the Arctics. The needles are perhaps $\frac{1}{2}$ to $1\frac{1}{2}$ inches broad in the middle, and 5 to 10 inches long, or as long as the ice sheet is thick. When first an open strip of water is formed, these needles, either by themselves or by the wash of the water, fall asunder; they will tip over and, their whole surface being exposed to the warmer water, they will thaw away quickly. The formation of this peculiar structure of the ice is somewhat shrouded in mystery; but it seems to be due to a certain succession of temperature variations with the subsequent expansions and contractions of the ice. This does not explain, perhaps, why sometimes penknife-ice is formed where only a short distance away the ice is compact.

When water freezes it expands with great force, and exerts a pressure which Trautwine estimates at not less

* Approximately:

$$(H_1 - H)^2 = k_1 \sum_0^n (T - 32)$$

where k_1 perhaps is about 2·6.

than 30,000 pounds per square inch. The ice-sheet, therefore, when formed on a lake, crowds its edge against the shore. With a fall of temperature the ice must contract; but being held at its edges by the friction on the sides, it cracks and opens into vertical fissures, or is, through its whole body, subjected to interior horizontal stresses. Therefore, the natural cleavage of the ice is always in vertical planes. Water enters these fissures for at least ten-elevenths of their depth, and often, lifted by capillarity, to the upper surface of the ice, in freezing it fills them with compact ice. When the temperature again rises, the whole ice-body expands and, the old fissures being filled, a compression takes place which may produce new fractures. At the same time a thrust or shove is exerted towards shore, by which the ice is forced up the side-slopes, carrying with it boulders and loose material. A subsequent fall of temperature gives rise to new cracks, the water in them freezes and warmer weather again produces a shoreward thrust. Thus, the "shore wall" of the geologists is formed and the ice may be piled up to great heights. Having been exposed repeatedly to such expansions and contractions, the ice is strained in a similar way to that of the well-known glass toys, known as Prince Rupert drops. By a sudden shaking or percussion, it (the ice) may, like the glass drops, fall to pieces, forming a lot of needles very much like the prismatic vertical bodies into which granite, basalt or other plutonic rocks may cleave, this prismatic structure, perpendicular to the cooling surface, being common to other materials slowly solidified from a state of fusion.

The rate of expansion and contraction per degree F. for ice was found by Dumble to be 0·00000765 (0·0000033 at the freezing point), and, later on, by Andrews, for temperatures 32°–16°, 16°–0°, 0°– —21°, —21°– —30°, respectively: 0·00004088, 0·00002804, 0·00002048 and 0·00001974. This is more than for nearly any other solid.

It is evident that the interior strains produced by the temperature variations must influence the strength of the ice. Hence, the physical constants of crushing and tensile strength, elasticity, etc., must vary greatly with the present

and former temperatures, even though we limit ourselves to consider only hard, solid and compact ice, neither cracked nor "rotten." Likewise do they vary with the purity of the water, its content of salts, etc. Trautwine gives the crushing strength of firm ice as 167–250 pounds per square inch. Colonel Ludlow, in his experiments in 1881, on 6–12-inch cubes, found 292–889 pounds for pure hard ice, and 222–820 pounds for inferior grades, and, on the Delaware River, 700 pounds for clear ice and 400 pounds or less for the ice near the mouth, where it is more or less disintegrated by the action of salt water, etc. Experiments of Gzowski gave 208 pounds; those of others, 310–320 pounds. The tensile strength was found by German experiments* to be 142–223 pounds per square inch. The shearing strength has been given† as 75–119 pounds per square inch.

The coefficient of elasticity has been determined in different ways. By cutting out of the ice, floating on the water, along its three sides, a long and narrow rectangular strip, and loading the extremity of this tongue with weights, Bevan found a modulus 77×10^7 pounds per square inch; but here the resistance of the water or the buoyancy influences the result. Trowbridge and Rae ‡ removed the ice from the water and determined its elasticity by comparing the transverse vibrations of ice bars (13–13·7 inches long, 0·6–0·7 inch diameter) with those of a tuning fork, by measuring the transverse deflections of ice beams (3–7 feet long, 1·8–9 inches broad, and 1·8–4·3 inches thick), and by measuring the velocity of sound in ice. They found the latter to be 9,514 feet per second. The modulus of elasticity, as found by these experiments, was, respectively, 87×10^7, 102×10^7, 119×10^7, by longitudinal vibrations 122×10^7, and, by the rise of the deflected beam after removal of the load, 82×10^7; or, as an average of all, $M = 119 \times 10^7$ pounds per square inch (84×10^9 grams per square centimeter.)

* *Engineering News*, **14**, 1885.

† *Nature*, **1**, 1870.

‡ *Am. Journ. of Science and Arts*, **129**, 1885.

To determine now by means of these physical constants what weight an ice sheet of a certain thickness can safely carry, we must consider separately the different cases which may occur. The ice may support a single weight in one point, or be uniformly loaded all over its surface. It may rest on the water, or this support may have been withdrawn by a lowering of the water level, such as usually takes place when the springs are frozen and the water evaporates, is absorbed by the soil, or runs off. It should also be borne in mind that the ice, according to Faraday, consists of distinct layers of different fusibility, perhaps alternately with and without a content of salts, perhaps only due to its above-mentioned intermittent growth. This naturally tends to weaken the ice, as also do air-holes formed by the confined air bursting it.

The army rules are that 2-inch ice will sustain a man or properly spaced infantry; 4-inch ice will carry a man on horseback, or cavalry, or light guns; 6-inch ice, heavy field guns, such as 80-pounders; 8-inch ice, a battery of artillery, with carriages and horses, but not over 1,000 pounds per square foot on sledges; and 10-inch ice sustains an army or an innumerable multitude. On 15-inch ice, railroad tracks are often laid and operated for months, and 2-feet-thick ice withstood the impact of a loaded passenger car, after a 60-feet fall (or, perhaps, 1,500 foot-tons), but broke under that of the locomotive and tender (or, perhaps, 3,000 foot-tons).

A theoretically correct calculation of the sustaining power of an ice sheet is hardly possible. We can establish the general equations, but merely attempt at an approximate solution of them, except in special cases.

For a plane of equal flexibility in all directions, subjected only to vertical exterior forces, Thompson and Tait* deduce the following equation for the strain z:

$$A\left(\frac{d^4z}{dx^4} + 2\frac{d^4z}{dx^2dy^2} + \frac{d^4z}{dy^4}\right) = A\nabla^2\nabla^2 z = Z - \frac{dM}{dx} - \frac{dL}{dy}$$

where x, y, z are the co-ordinates of a point, the $x\,y$ plane being the original unstrained plane. $Z\,d\,x\,d\,y$ is the

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* "Natural Philosophy," Cambridge, 1883.

sum of the exterior forces perpendicular on the element $dx\,dy$, $M\,dx\,dy$ and $L\,dx\,dy$ the couples around the x and y axes, introduced by removing the different perpendicular forces from their points of application on the area $dx\,dy$ to its center of inertia.

For a circular strain, produced when the forces act in concentric circles, is:

$$\frac{dM}{dx} + \frac{dL}{dy} = 0$$

and hence:

$$A\,\nabla^2\,\nabla^2 z = Z \tag{10}$$

Considering the ice as homogeneous and isotropic (in spite of its decidedly heterogeneous and colotropic nature), we have for A, the cylindrical rigidity of flexion, the following expressions:

$$A = \frac{1}{12}\,\frac{M\,h^3}{1 - \alpha^2} = \frac{n}{3}\,\frac{3k + n}{3k + 4n}\,h^3 = \frac{1}{3}\,\frac{m\,n}{m + n}\,h^3 = \frac{n}{6}\,(1 + \beta)h^3$$

where h is the thickness of the ice; M, Young's modulus of elasticity; α the ratio of linear contraction to linear elongation; k the volume-modulus; n modulus of rigidity, $m = k + \frac{1}{3}\,n$, and β the ratio of transversal stress to longitudinal stress corresponding to a single longitudinal strain. Substituting for α its approximately constant value, $\frac{1}{4}$ (according to Poisson) or $\frac{3}{10}$ (according to Bach), we have approximately:

$$A = 0{\cdot}090\,Mh^3$$

the coefficient ranging from 0·089 to 0·092

The strain z being a function of the radius $r = \sqrt{x^2 + y^2}$, we may transform (10) to

$$\nabla^2\,\nabla^2 z = \frac{d^4 z}{dr^4} + \frac{2}{r}\,\frac{d^3 z}{dr^3} - \frac{1}{r^2}\,\frac{d^2 z}{dr^2} + \frac{1}{r^3}\,\frac{dz}{dr} = \frac{Z}{A} \tag{11}$$

the integral of which contains four arbitrary constants. These are determined by the following conditions:

$$\frac{dz}{dr} = 0 \text{ for } r = 0$$

$z = 0$ and bending moment around circular arc, $G = 0$ at shore ($r = R$); shearing stress along circle of radius r:

$$2\pi r S = \int_0^r 2\pi r Z d r + P$$

for all values of r, P being any exterior vertical forces applied to single points inside the circle.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting of October 15, 1895.

DR. WM. C. DAY President, in the Chair.

WHAT IS BITUMEN?*

BY S. F. PECKHAM.

The exact meaning of the word "bitumen," in modern scientific literature, has been a matter of perplexity for many years. It has appeared to me impossible that any one unacquainted with the different substances included by the makers of dictionaries and cyclopædias under their descriptions and definitions, could form any clear idea of what they are. For instance, in Genesis xi, 3, a Hebrew word occurs which designates the substance used in constructing the walls of the tower of Babel. In the Septuagint this word is translated ἄσφαλτος, and in the Vulgate, "bitumen." In the Bishop's Bible of 1568, and subsequent translations into English, the word is rendered "slime." In the Douay translation of 1600 it is "bitume." In the Protestant French translation it is "bitume." In Luther's German Bible it is "thon." In removing the magnificent alabaster slabs that were used to adorn the palaces of Nineveh and Babylon, it has been discovered that the material used to cement and hold the slabs in position, was melted or natural maltha. The word "asphaltum" is said to be derived from

α, privitive, and *σφαλλο*, "I cause to slip." It therefore signifies a substance that prevents one from slipping, and was applied to the solid forms of bitumen that soften in the sun. This substance was not rare in so-called Bible lands, embracing the valley of the Euphrates, the table lands of Mesopotamia and the valley of the Jordan. It was of frequent occurrence along the shores of the Dead Sea, and was gathered and sold in the caravan trade that passed through the land of Moab and Petrea into Egypt.

During the Middle Ages, asphaltum and other forms of bitumen appear to have found but few uses, and they are but seldom mentioned. The words bitumen, asphaltum, petroleum and naphtha, appear to have been used with different meanings, and also interchangeably or synonymously; yet, the words were generally used to signify a thing that was located and defined by further description, so that the bitumen of the Dead Sea was recognised as asphaltum, or solid bitumen; that of Zante, as petroleum, etc. It is only within the last century that any serious confusion in nomenclature has appeared, and then the trouble has arisen out of commercial rather than scientific considerations. About the year 1830, the French schist oil began to assume importance. Later, the Scotch paraffine industry arose, and during the decade from 1850 to 1860 extended from Scotland to the United States, into which both the materials used and the methods of manufacture were imported. In France the materials used were properly called "the bituminous shales of Autun." In Scotland the material was called boghead coal, boghead shale and boghead mineral; it was also called Torbanite. The expense attending the importation of the boghead shale into the United States, led the Downer Kerosene Oil Company, of Boston, Mass. and Portland, Me., to make an exclusive contract for the use of the Albertite, of New Brunswick. It was called Albert coal, asphalt, pitch, etc.; and, for commercial reasons, became the subject of a very important lawsuit, in which, as experts, scientific men gave very conflicting testimony, one party claiming that the material was asphaltum, and the other that it was coal. It was finally decided that the material was not coal, and did

not belong to the Crown.[1] At about this time, a deposit occurring in West Virginia, and since known as Grahamite, and which, in appearance, is much more like splint coal than Albertite, attracted attention. There were veins of material in Cuba that were also included in the argument, Coal *vs.* Asphalt.

The word "petroleum" assumed commercial importance about the year 1860, as designating certain natural oily fluids obtained from springs or wells, and that, by refining, could be converted in large part into illuminating oils. At about the same time the solid bitumen of the island of Trinidad began to attract attention as a possible crude material for the same purpose. It was only as late as 1865 that the petroleum mania became general, and that the interest in the contest, Coal *vs.* Asphalt, was allowed to subside. At that time nearly every bitumen spring in the world became the center of developments for the production of petroleum by artesian borings. The result was the introduction into commerce of many grades of petroleum that were chiefly distinguished by differences in density and the amount of oils of certain specific gravities, and suitable for certain purposes, chiefly illumination, to be obtained from them.

The researches of Pelouze and Cahours[2] and Warren and Storer showed that the Pennsylvania petroleums examined by them consisted chiefly of paraffines and isoparaffines, the lowest member of which is marsh gas.[3] Although I had shown in 1868[4] that the Pacific Coast petroleums contained a notable percentage of nitrogen, and that they could not be made to yield illuminating oils equal in quality to those obtained from Pennsylvania petroleum; also, that asphaltum and maltha were products of the decompo-

[1] Taylor's Statistics of Coal, Philadelphia, 1855, p. 516. Taylor's deposition before the Supreme Court at Halifax, N. S., respecting the asphaltum mine at Hillsborough, Philadelphia, 1851. On a New Variety of Asphalt. C. M. Wetherell. *Trans. Am. Philos. Soc.* (N.S.), **10**, 353.

[2] *Compt. Rend.*, **56**, 505; **57**, 62. Annales de Chimie et de Physique, (4) **1**, 5.

[3] *Mem. Am. Acad., N. S.*, **9**.

[4] *Proc. Am. Philos. Soc.* (N. S.), **10**, 445.

sition of these petroleums from natural causes; nevertheless, some of the ablest writers on petroleum continued to speak of the "petroleum springs of the Southwest," as though petroleum, maltha and asphaltum had never been defined, and millions of dollars had not been lost in attempts to obtain petroleum, as it was then known in Eastern commerce, in the valleys of Southern California, and to refine it into the best qualities of burning oils. In the fall of 1865, Drs. John Torrey and C. T. Jackson visited the center of operations on the Ojai[5] Ranche, now known as the Upper Ojai, and described as "a petroleum cascade," a hillside where a stream of maltha issued high up towards the crest of the Sulphur Mountain, and, spreading in the sun, trickled over several hundred feet of shale precipices. Any one ascending to the crest of the Sulphur Mountain, by the road leading from the Upper Ojai, can now see the same thin stream of maltha glistening in the sun, as it appeared to Messrs. Torrey and Jackson. As I saw it a year ago, there had been no apparent accumulation of material in twenty-nine years.

The wrangle over the question, whether there was any petroleum in Southern California at all, was carried on with great bitterness in 1864–5. It was really a wrangle over words more than things, for at that time, practically no petroleum worth mentioning had been found in Southern California—only just a little, enough to give a color of truth to the assertion that it was found there, thus making it possible to impose on Professor Silliman, as was done.

I have lately re-read the report that I made to the California Petroleum Company in January, 1866, and find that I then supported my statements that the bitumen of that region was maltha, and not petroleum, by references to Dana's "Mineralogy" and Dr. Ure's "Dictionary of Arts, Manufactures and Mines." These works were then well known, and had been printed many years. I thus proved that maltha was no newly discovered substance, and that, like petroleum and asphaltum, it had long been known and

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[5] Ojai, pronounced O-hī.

described. These definitions are not confined to the English language, but are just as well recognised in both the French and German languages.

It therefore appears to me to be quite worthy of careful consideration that, within the last five years, a patent case should have obtained any standing at the Patent Office or before the Courts of the United States, wherein the only real point at issue was the continued misuse and misconstruction of the word bitumen and the species under it.

The history of the case was as follows: One Beardsley, who was in Southern California when I was there in 1865, patented a process for smearing paper with hot residuum from the distillation of California petroleum. As described by him, the material might also be purified asphaltum, obtained by dissolving asphaltum in petroleum, allowing the dirt to settle and distilling to a residuum the solution thus obtained. If he had called his residuum "asphalt," as others do, the patent would have been rejected; so he called it "maltha," and described it as the "solid residuum of heavy petroleum." He might just as well have called it "butter" or "guava jelly," and have defined it as he did, for no such definition of the word maltha was ever given before. This patent was allowed and issued. Then he applied for another patent on an operation that consisted in dissolving his "maltha" in carbon disulphide and applying the solution to paper. This patent was also issued, probably for the reason that the Patent Office officials did not understand the misuse of the word "maltha," and thought that a new substance was being dissolved in carbon disulphide. After various commercial evolutions, these patents became the property of the Paraffine Paint Company, on the Pacific Coast, and of the Standard Paint Company of New Jersey, in the Eastern States. They obtained their "maltha" from the Union Oil Company of California, whose works are located at Santa Paula, Ventura County, Cal. After a time, one H. J. Bird commenced the manufacture of coated paper by applying a mixture of Trinidad pitch, Carnuaba wax, wax tailings and coke pitch, neither of which was Beardsley's "maltha," or any other maltha. Meantime, the Stand-

ard Paint Company began using coke pitch, a well-known commercial product, obtained as a residue from the destructive distillation of petroleum tar. The case was brought against Bird for infringement, and has just been decided in Bird's favor, from first to last, by the full bench of the U. S. District Court, sitting at Trenton, N. J. The case was in litigation five years and ruined Bird financially.

The ground of contention was that coke pitch, being a residuum of petroleum, was Beardsley's "maltha." While the word maltha was well known to mean "mineral tar," and had had that meaning for an indefinite period, it was claimed that the action of the Patent Office in granting Beardsley's patent had "fixed the meaning of the word 'maltha' for the purpose of coating paper;" hence, Bird infringed, although he used a mixture of four substances, in neither of which was Beardsley's "maltha" as used by him. A noted expert maintained that Bird's mixture was identically the same thing as Beardsley's "maltha," because both were black, shiny, had a conchoidal fracture, and were tasteless and odorless. Since the confusion of tongues at Babel, no such confusion of names and things and mixtures of things was ever witnessed as, in this case, confounded all forms of bitumen, and all of the artificial products having properties similar to, or identical with, natural bitumens. And yet, in spite of a vigorous and able defence, it was allowed to drag along for years in an attempt to monopolise a business where invention can only apply new materials by an old process long since exhausted of patentable elements.

Again, the Bibliothèque Scientifique Internationale has just issued a posthumous work by the late eminent Swiss geologist, August Jaccard. The work is entitled "Le Petrole, l'Asphalte et le Bitume,"[6] a title in which the species is made to include the genus. The work presents the subject "au pointe de vue geologique," and for this reason many errors and defects may be overlooked from the standpoint of other branches of science. The book seeks the

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[6] Le Petrole, l'Asphalte et le Bitume, par A. Jaccard, Paris. Germer Ballière et Cie, 1895.

plane of the general intelligent reader, and, despite the many grave defects that I have elsewhere pointed out, has much to recommend it; yet, in respect to the nomenclature of its principal subject, "Bitumen," it is particularly and unfortunately confused. Indeed, I do not see how a person who is not to some extent familiar with the subject, and who, therefore, reads with considerable discrimination, can clearly understand the meaning of many passages. The entire nomenclature of bitumen is used with such a confusing disregard of clear distinctions—the same word being used in different places with a different meaning—as to detract much from descriptions otherwise of great value, for there is probably nowhere to be found so complete a *resumé* of the literature extant relating to the asphaltic limestones of the upper valley of the Rhone.

It therefore seems to me desirable that the word bitumen should be once more, and clearly, defined, as the generic name of that large class of substances occurring in nature as minerals, and consisting chiefly of mixtures of compounds of carbon and hydrogen, with nitrogen, sulphur and oxygen as more rare constituents. Under this genus should be ranged, as species and sub-species, all of the natural combustible gases, naphthas, petroleums, malthas and asphaltums.

These gases include free hydrogen, carbon monoxide and all of the initial members of the different series of hydrocarbons that have been found in petroleums, together with others in each series that exist as free gases at comparatively low temperatures. These natural gases are not constant in composition, even when issuing from the same spring or well; nor are they found to be alike in composition when gases from localities yielding essentially unlike varieties of bitumen are compared. It would, therefore, be a fruitless task to attempt to give a name to natural gas as a mineral species that was in any manner derived from the chemical composition of any particular specimen of gas. It can only be described as a gaseous form of bitumen, distinguished from other natural gases by being combustible.

The word naphtha is said to be derived from the Persian

word *nafta*, and was originally used in Western Asia to designate certain fluid forms of bitumen that have an ethereal, rather than an oily consistency. In those localities, notably Asia Minor and Persia, where this class of bitumens abounds, the name "naphtha" was applied to all of the fluid forms of bitumen. From this source the word passed into Europe, where, until quite lately, it was generally used instead of petroleum. Practically, in the languages of modern Europe, the words naphtha and petroleum are synonymous, as applied to the fluid forms of bitumen.

The word petroleum, signifying rock oil, from its derivation, is properly applied to oily rather than viscous fluids. The viscous forms of bitumen, passing by insensible degrees into semi-solid or solid forms, have been designated by some French writers as "bitume glutineux," and by others as maltha. In the United States some writers describe all forms of bitumen, between natural gas and asphaltum, as petroleum, sometimes qualifying given specimens as "very light," "very heavy," "viscid," etc. This obscurity first arose in Europe, from a lack of detailed knowledge concerning the chemical constitution of fluid bitumens. De Saussure analysed the "Naphtha of Amiano," in 1817,[7] as if it were a homogeneous substance, and Boussingault, in 1837,[8] prepared his celebrated memoir upon the "Composition of Bitumens," apparently with the idea that he had separated the maltha of Bechelbronn into petroleum and asphaltum, each of which were analysed as if they also were homogeneous substances. In the United States, prior to the discovery of the Trenton limestone oils, it was assumed that there was no essential difference in petroleums, except in the proportions of the several ingredients mixed together in the oil.

True, Warren and Storer had shown, in 1865,[9] the essential unlikeness of Rangoon and Pennsylvania petroleum, and later, I, myself, showed the large amount of nitrogen in

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[7] *Annales de Chim. et de Phys.* (2) **4,** 314–320.

[8] *Ibid,* (2) **64,** 141. *Jour. Frank. Inst.,* **24,** 138.

[9] *Mem. Am. Acad.,* N. S., **9.**

California oils; but Prof. J. D. Dana[10] apparently preferred to consider petroleums as rocks rather than species, and in his "System of Mineralogy," inserted Warren's series of paraffines and isoparaffines as species, although at the same time he made species of Albertite, Grahamite, etc., which we now have a right to believe, I think, only differ from liquid petroleums in the members of the paraffine and other series of hydrocarbons, which they contain. Quite lately, Maybery[11] has shown that the Trenton limestone oils contain compounds of sulphur; and Salathé and myself have discovered the esters of the pyridin and other benzole bases in California petroleums,[12] and there are very good reasons for concluding that they are constituents of all the tertiary petroleums of the Pacific Coast of both North and South America. It has been further shown that the Russian petroleums consist of hydrobenzoles,[13] while there are many reasons for believing that there are several other groups yet to be determined among European liquid bitumens. In the United States, also, there is clearly to be distinguished from all others yet investigated, a group found in the great interior valleys of the eastern slope of the Rocky Mountains, extending from Texas north into British America and the valley of the Mackenzie River.

Some of these fluid varieties of bitumen, both in Europe and America, pass, by insensible degrees and through natural causes, into maltha, which is a semi-fluid, viscous form of bitumen, known as mineral tar, and just as clearly to be distinguished in consistence from petroleum as common tar is to be distinguished from olive oil. I have found the change by which California petroleum is converted into

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[10] Dana's Mineralogy, fifth edition, 1869. I am aware that in the edition of 1892 the arrangement more nearly approaches that suggested in this paper.

[11] *Jour. Frank. Inst.*, **139**, 401.

[12] *Am. Jour. Sci.*, (3) **48**, 250.

[13] Beilstein u. Kurbatow, *Ber. d. Deut. Chem. Ges.*, **13**, 1818; Schützenberger et Jonine. *Bul. Soc. Chim.*, Paris, 1880, p. 673. Since the above was written, a memoir by Wanklyn and Cooper has appeared in the *Chem. News.*, **72**, 7, in which it is shown that a new group, called by them "keroses," exists in Russian kerosene.

maltha to be due to two causes, viz.: evaporation and indirect oxidation.[14] By this latter term, I mean, not that oxygen becomes to any extent a component of the maltha, if at all, but that by oxidation and removal of hydrogen the molecules are condensed as the proportion of carbon increases. Prof. Henry Wurtz would have us believe that this change is due to polymerisation.[15] I cannot interpret the results of my experiments as indicating such a result alone. When air, ozone, or chlorine, is passed through the paraffine petroleums, they are condensed by evaporation to a residue resembling vaseline. When California petroleums are treated in the same manner, they are condensed by decomposition into, first, maltha, and then asphaltum. Chlorine will effect this change just as readily as ozone.[16] Destructive distillation will also effect the same or a similar change, the residue being either an asphaltic residuum, or coke, and the distillate a hydrocarbon richer in hydrogen than the original bitumen. The natural malthas contain both water and air in mechanical admixture.

When the solid forms of bitumen are reached, the want of clear distinctions becomes still more pronounced. The work of M. Jaccard affords an illustration of the lack of clear ideas expressed in clear language, in which some authors indulge. The late Dr. T. Sterry Hunt, as long ago as 1863,[17] separated pyrobituminous from bituminous minerals. This important consideration, while not wholly disregarded by M. Jaccard and other authors, does not appear to be fully appreciated by him. The fundamental principle underlying the use of this word exists in the fact that "pyrobituminous" coals, schists and shales yield, on being heated to destructive distillation, products that resemble bitumens. Why this clearly scientific, wholly reasonable and very convenient basis of classification has not been made the foundation upon which all scientific dis-

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[14] *Am. Jour. Sci.*, (3) **48,** 254.

[15] *Engineering and Mining Journal*, 1889, 1890, 1891.

[16] *Proc. Am. Philos. Soc.*, **10,** 445.

[17] *Am. Jour. Sci.*, (2) **35,** 157. Chemical and Geological Essays. J. R. Osgood & Co., Boston, 1875.

cussions relating to bitumens proceed, whether from the point of view of geology or any other point of view, it is difficult to explain. Yet, until this distinction is fully recognised, writers will continue to mix up bituminous coals, schists of Autun and Mansfeld, boghead mineral, etc., with all sorts of bitumens, as M. Jaccard has done, to the infinite confusion of the discussion of bitumens. These coals, schists and shales are nearly as insoluble in the solvents of bitumen, viz.: ethyl ether, chloroform, benzole, etc., as they are in distilled water; hence, Dr. Hunt made the action of these solvents exclusive of the two classes of substances. All true bitumens are miscible with, or almost wholly soluble in, chloroform, a test that clearly separates them from pyrobituminous minerals. So-called "asphaltic coals" are not coals at all, but are simply geologically old asphaltums.

In whatever manner bitumens may be classified, it is apparent from the outset that there are a large number of minerals, consisting in part of true bitumens, that are, strictly speaking, rocks. To this class of substances belong the bituminous sandstones and limestones of the upper valley of the Rhone, the Limmer and Ragusa rocks, the Niagara limestone of Chicago, the bituminous limestones of Utah, the Turrellite of Texas, the sandstones of Kentucky, the Indian Territory and the Athabasca River and California. These are found as beds of sedimentary or crystalline rock, often of immense extent and thickness, impregnated with bitumen of varying consistency and quality, sometimes nearly fluid, but never solid, after being separated from the rock. In some instances the bitumen appears to be convertible into asphaltum, and in others not. The French writers have called these rocks "asphalte," but unfortunately they have also called asphaltum by the same name, as if the things were identical and the words synonymous. Among English writers no uniform custom prevails, but German authors use generally the French word. I think it would promote clearness of expression if this word "asphalte" were uniformly introduced into all modern languages to designate these bituminous rocks, with the quali-

fying words, siliceous, calcareous or argillaceous, added as required.[18]

The so-called Trinidad pitch, as it is found in and around the lake, is a unique mixture of bitumen, water, mineral and vegetable matter, the latter usually determined as "organic matter, not bitumen," and the whole inflated with gas. When removed from the deposit, the water rapidly dries out, the gas escapes, the mass becomes brittle and changes from a brown to a blue-black color, acquiring a sticky consistency as it loses water. At a rough estimate, less than 25 per cent. of the mass of the natural cheese pitch is bitumen; it is, therefore, quite improperly called the largest deposit of bitumen in the world. I think that the Trinidad pitch, so-called, is properly to be considered a mineral species, and I suggest for it the name "Parianite," in reference to the formation in which the celebrated lake occurs.

The words natural gas, naphtha, petroleum, maltha, asphaltum and asphalte, are not names of things, but words which indicate accidents of occurrence, to which any species of bitumen may be subject. When a true system of classification of the species and sub-species under bitumen has been reached, it will be found that a species may occur in nature in any or all of the several conditions, from natural gas to asphalte. A true system, therefore, must name and classify the bitumens themselves. As an illustration of my meaning, I would suggest that the constitution of Pennsylvania petroleum, having been first shown by C. M. Warren to consist in a mixture of paraffines, isoparaffines, etc., this species of bitumen embracing the natural gas and petro-

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[18] Last December, Miss Laura A. Linton published a paper in the *Journal of the American Chemical Society*, upon the "Technical Analysis of Asphaltum." In this paper the words asphalt and asphaltum were used interchangeably. The paper was reprinted in the London *Chemical News*, and the careful editor added the letter e to asphalt wherever it occurred. I have looked through all of the English and American dictionaries, from Samuel Johnson's down, and through all of the cyclopædias printed in English, to which I have access, including the ninth edition of the Britannica, and I cannot find the word asphalte anywhere as an equivalent for asphalt. Asphalte is not an English word.

leum of western Pennsylvania, eastern Ohio and West Virginia, may properly be named "Warrenite." As Prof. C. F. Maybery has first clearly pointed out the characteristics of the Trenton limestone oils by means of his researches upon the sulphur compounds contained in them, I would suggest for this species of bitumen the name "Mayberyite." As the California bitumens containing the esters of pyridin, etc., are largely found in Ventura County, I would suggest for them the name "Venturäite."

I am aware that these suggestions are based upon data very inadequate for the purpose of complete classification, yet I contend it is a classification that will classify things and not names, and, in time, may be made sufficiently complete for the purposes of mineralogy as well as technology.

The old terms will still have their places and uses by which to indicate the physical conditions under which these different mineral species are found. As an illustration, I will suggest that a description of "Warrenite" would include the statement that it is found as natural gas, naphtha, petroleum, etc.; that it consists of paraffines, isoparaffines, olefines, a trace of benzoles, etc. Analyses might be given from the researches of Warren and Storer, Pelouze and Cahours, Ashburner, etc. It occurs along the western slope of the Allegheny Mountains, from New York to southern Kentucky, in natural springs and artesian borings.

"Mayberyite" is found as natural gas, petroleum and maltha; it consists of paraffines (?), isoparaffines (?), olefines (?), esters of the pyridin bases (?), and Maybery's sulphur compounds. Give analytical references. It occurs in the petroleum region of Canada, in northwestern Ohio and Indiana, and southward.[19]

"Venturäite" is found as natural gas, petroleum, maltha and asphaltum; consists of hydrobenzoles (?) esters of pyridin bases, etc. It occurs throughout Southern California, as petroleum in artesian borings; as maltha saturating

[19] In one instance, I obtained a qualitative reaction for the pyridin bases in a sample of commercial "lima tar." I have not yet been able to verify their presence in other and authentic samples.

sand at Las Conchas, in enormous springs on the Ojai, and in many other localities; as asphaltum, in veins of immense extent, probably the largest in the world, at Asphalto, Kern County, Cal.; also at La Patera, Santa Barbara County, in the same State.

It goes without saying that there has been no scientific examination of any solid bitumen that is worth mentioning, consequently any attempts at specific description like those given above are like a skimmer, consisting chiefly of vacant spaces. Nevertheless, shall we go on multiplying words about the "bitumen of the Dead Sea," "Trinidad pitch," "California asphalt," etc., or shall we begin to learn by first discovering how difficult it is to answer the question: "What is Bitumen?" Let those who think they can answer it first read M. Jaccard's book.

UNIVERSITY OF MICHIGAN,
ANN ARBOR, MICH., August 24, 1895.

ON THE TECHNICAL ANALYSIS OF ASPHALTS.

BY SAMUEL P. SADTLER, PH.D.

In an article published in the *Journal of the American Chemical Society*, for December, 1894, Miss Laura A. Linton gave, under the above heading, a most valuable discussion of the present methods of asphalt analysis. As she well says, the "petrolene" of the writers on asphalt "is nothing but a name that covers a great variety of substances, radically unlike, that exist in different forms of bitumen, and are only related in this instance as being held in solution by a certain limited number of menstrua, and which include the whole list of paraffines and isoparaffines, the olefines, the benzenes and additive benzenes, with many other less abundant and well-known substances." Similarly, "in a general way, it may be said that asphaltene is that portion of the different forms of bitumen that is soluble in carbon disulphide, chloroform, benzene, and a few other less known

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* Read at the meeting of the Chemical Section, September 17, 1895.

liquids, and is not soluble in the menstrua that dissolve petrolene."

Miss Linton recommends, therefore, as a process for uniform treatment of asphalts, to digest them first with petroleum ether, decanting the liquid upon a filter, and ultimately the undissolved bitumen also. After getting the weight of the filter and contents, it is treated with boiling turpentine, with which it is digested for some time, the funnel being covered. After repeating this treatment until the filtrate becomes colorless, chloroform is taken to finish the extraction of the asphaltene. After another weighing of the filter and its contents, it is to be burned in a platinum crucible, in order to determine the organic non-bitumen and ash.

This process of Miss Linton, while giving results that are comparable, becomes very tedious in practice, besides requiring the use of three solvents, of which one (the boiling turpentine) is unsatisfactory because of its resinous and sticky tendency.

I have sought, therefore, to find a more expeditious process without sacrificing completeness of extraction, or allowing the results to fail in comparability.

With this in view, I have chosen a form of apparatus in which a continuous extraction can be carried out without requiring the transference of the weighed sample from one vessel to the other. The solvents chosen are definite compounds of fixed boiling point, which can always be had pure and subject to no alteration; the extraction goes on continuously at the boiling point of the solvent; and the solvents are recovered for use again.

The solvents chosen are acetone, as a substitute for the petroleum ether, for the extraction of the petrolene; and chloroform, for the extraction of the asphaltene. Both acetone and chloroform can be had perfectly pure, and are not alterable, so that they possess distinct advantages over petroleum ether and carbon disulphide.

The analysis is carried out as follows:

An asbestos filter is made in a weighed Gooch crucible, and dried. About 10 grams of fine white sand, previously

ignited and cooled, is added, and a piece of stout platinum wire, about 3 inches long, is placed in the crucible, and the whole dried to a constant weight at 100° C.

Then 1 to 2 grams of the asphalt, in fine powder if a solid, are added, gently mixed with the upper portion of the sand layer with the aid of the platinum wire, care being taken not to disturb the asbestos filter below. The weight of the whole is accurately taken, inclusive of the wire and the crucible, and its contents are then dried at 100° C. to a constant weight, either in an air bath or water oven, cooled in a desiccator and weighed. If the sample be a maltha (liquid bitumen), it is gently mixed with the sand layer, after slightly softening it with the aid of the drying oven. The loss at 100° C. is calculated and called "moisture and loss at 100° C." The crucible and its contents are then placed in a continuous extraction apparatus, formed by placing a small percolator within a larger one, the inner one being held in position by a perforated cork. The crucible having been placed in the inner percolator, the outer one is connected with a flask containing the solvent, and with an upright condenser. The flask is heated either on a sand bath or a water bath, the former being preferable, since when once regulated it needs no attention or renewal as does the water bath. The extraction with acetone, which is first undertaken, is continued until the loss on extracting for two hours is not more than 1 or 2 milligrams. The loss of weight after this extraction, as compared with the weight on starting the extraction, is calculated and called "petrolene." The extraction is then continued in the same manner with chloroform, and the final loss is the "total bitumen." The time necessary to effect a thorough extraction varies greatly with the different asphalts, but will not amount to more than twelve hours for the acetone and eight hours for the chloroform extraction. The loss in weight should be taken first after four hours, and then every two hours until the extraction is complete, the crucible and contents being dried at 100° C., and cooled in a desiccator each time. The residue in the crucible then represents the organic non-bitumen and mineral matter. It is ignited, after placing the

cap on the bottom of the crucible, and the loss calculated as "organic non-bitumen," while the remainder is the "mineral matter" or "ash."

Duplicate analyses of two well-known varieties of asphaltum were made to test the method:

REFINED TRINIDAD ASPHALT.

	I.	*II.*
Petrolene	46·40	46·41
Asphaltene	15·14	15·20
Organic non-bitumen	3·02	2·95
Mineral matter	35·44	35·44

REFINED BERMUDEZ ASPHALT.

	I.	*II.*
Petrolene	66·47	66·45
Asphaltene	29·66	29·71
Organic non-bitumen	1·76	1·73
Mineral matter	2·11	2·11

As an example of a maltha, or liquid bitumen, examined by this method, may be given the following analysis of

ALCATRAZ LIQUID ASPHALT.

	Per Cent.
Petrolene	89·21
Asphaltene	9·39
Organic non-bitumen	trace.
Mineral matter	1·40

In publishing this note I wish to acknowledge my indebtedness to Mr. H. Blount Hunter, my assistant, for the very intelligent and skilful way in which he has carried out most of the experimental work.

PHILADELPHIA, September 17, 1895.

NOTES AND COMMENTS.*

CASTNER'S ELECTROLYTIC METHOD FOR PRODUCING CHLORINE AND ALKALI.

At the Fourteenth Annual Meeting of the Society of Chemical Industry, lately held at Leeds, England, the president, Prof. T. E. Thorpe, in his address, made the following allusion to the interesting process of Mr. Hamilton Castner for the electrolytic decomposition of alkaline chlorides, several references to which have lately appeared in the *Journal*, viz.:

* From the Secretary's monthly reports.

"The application of electrical energy to the decomposition of alkaline chlorides, either for the production of chlorine, or alkali, or of both products, has been made the subject of many patents. The great majority of these processes have been stillborn, and even of those which were stimulated into vitality, the existence has been short and feeble. With a sounder knowledge of the conditions under which alone success is possible, the problem is once more attracting the attention of technologists, and the chemical world is watching, with great interest, the results of two or three electrolytic processes which are now being worked out on the large scale. One of these is the invention of our member, Mr. Hamilton Castner, and has been in practically continuous operation for nearly twelve months, at the Aluminium Company's works, at Oldbury. In Mr. Castner's process, the difficulties connected with the use of diaphragms, and the liability to recombination of the products to form hypochlorite, are obviated, whereby the destruction of the electrodes is prevented, and a much higher electrical efficiency is obtained. I am indebted to Mr. Castner for the following account of the method: The essential feature of the process is the employment of a moving body of mercury, which completely separates the products of electrolysis, and, by its movement, takes the place of a diaphragm, the sodium amalgam formed being decomposed as it is formed. The cell, which is divided into three compartments, is capable of being continuously rocked or tilted, so as to cause the mercury to flow from side to side. The two outside compartments contain the alkaline chloride solution and the carbon anodes, while the middle compartment contains an iron cathode and the caustic solution. The solution of the chloride is continuously circulating through the outside compartments, wherein it is being electrolysed, and then returns to saturators, where it is re-charged with salt. The electric current, traversing the salt solution, liberates chlorine and forms sodium amalgam. The chlorine escapes from each cell, through an aperture, into a collecting main, while the sodium amalgam, by the continuous back-and-forward tilting of the cell, passes to the center compartment, where it acts as an anode during the passage of the current, the sodium going into solution as caustic. A regulated quantity of water is admitted hourly to the center compartment of each cell, causing the pure solution of caustic to overflow through a discharge pipe into a large collecting pipe connecting all the cells. The cells are electrically connected in series, and are capable of being cut out or put into operation at will."

FORCE REQUIRED IN DRIVING AND PULLING CUT WIRE NAILS*.

By Professor R. C. Carpenter.

The experiments described show the force required to drive and start the nails, and also the relative work in each case. To obtain some figures which would give not only the maximum force, but also the work required both for

* Abstract of paper read at the Detroit Meeting of the American Society of Mechanical Engineers June, 1895.

driving and pulling various nails, the writer had the following experiments conducted in the laboratory of Sibley College. Nails of various kinds were forced into a piece of Southern pine, which was as nearly homogeneous as was possible to obtain, by one of the heads of a testing machine, and the amount required at the end of each one-quarter inch of penetration was noted. The nails were driven within about one-quarter inch of their full length in each case.

In pulling, they were drawn out by a species of forceps attached to the testing machine, the force required being noted at each one-quarter inch. Diagrams were then drawn corresponding to the force exerted and the depth of penetration, the integration of these diagrams giving the total work either for driving or for drawing. Experiments were made on ten nails of each kind, and the averages taken to represent the work of any particular class.

The general summary of the experiments is given in the following table, from which it will be noted: (1) That very much more force is required to drive

SUMMARY OF EXPERIMENTS IN DRIVING AND PULLING NAILS IN SOUTHERN PINE WOOD.

No. of Nail.	Kind of Nail.	Number to One Pound.	Depth of Penetration. Inches.	Maximum Load to Drive. Pounds.	Max. Load to Start in Pulling. Pounds.	Work in Inch-pounds.		Maximum Weight per Pound of Nails in Tons.		Work in Foot-pounds per Pound of Nails.		Relative Efficiency.
						To Drive.	To Pull.	To Drive.	To Start.	To Drive.	To Pull.	
20d	Cut	23	3½	819·6	920·8	1,522·85	477·6	9·34	11·6	2,915	915·0	31·6
20d	Wire . . .	34	3½	376·0	318·0	864·6	472·8	6·41	5·42	2,450	1,335·0	54·5
10d	Cut	70	3	341·6	316·8	585·25	200·85	11·9	12·5	3,410	1,215·0	35·5
10d	Wire . . .	105	3	232·4	213·0	435·65	220·2	12·2	11·4	3,830	1,940·0	50·7
10d	Cut	—	3	483·0	518·0	699·75	284·7	—	—	—	—	41·0
	Sharpened:											
8d	Cut	88	2¼	312·4	328·4	419·1	140·1	13·7	14·5	3,038	1,019·0	33·5
8d	Wire . . .	132	2¼	198·8	167·2	278·6	104·6	13·2	11·1	3,340	1,255·0	37·5
6d	Cut	168	1¾	221·2	155·6	274·3	64·5	18·7	13·3	3,830	904·5	23·5
6d	Wire	252	1¾	134·6	87·6	165·2	62·75	16·9	15·0	3,480	1,320·0	38·0

a cut nail a given distance than a wire nail. (2) That more force is required to start a cut nail generally than to drive it, and that it invariably starts much harder than a wire nail. (3) The work in inch-pounds per nail required in driving cut nails is much more than that in driving wire nails. (4) The work in inch-pounds in pulling cut nails is about equal, sometimes less and sometimes greater, per nail, than that for pulling wire nails. (5) The maximum force per pound in driving or starting wire nails is more nearly equal to that of the cut nails than when estimated on the basis of that of a single nail, but it is still less. (6) The work, in foot-pounds, per pound of wire nails, re-

quired for driving is less than that required for the cut nail, and that for pulling is considerably more. (7) The relative efficiency which is here considered as the ratio of the work of pulling to that of driving, is much higher for the wire nail than for the cut nail.

In making experiments it was noticed that the cut nail bruised and broke the fibers of the wood, principally at the end of the nail, whereas, the wire nail simply crowded them apart, and probably did not move them much beyond the point from which they would return by elastic force, and hence the nail would be grasped much stronger per unit of area of surface by the wood. Presenting less surface there would be, however, less resistance to starting.

To see what the effect of change of form would be, a number of tenpenny cut nails were sharpened on the point by grinding to an angle of about 30°, so that the fibers in advance of the nail would be thrust aside, and not bruised and broken. This served to increase the holding power over the cut nail of ordinary shape about fifty per cent. in starting force and about thirty per cent. in work of resistance to pulling.

The good result produced in sharpening the end is shown by some experiments made some years ago in the Sibley laboratories on the holding power of ordinary railroad spikes, as compared with a Walcott spike, which differed from the ordinary railroad spike in having a sharp end, and also in having two longitudinal grooves stamped into one side.

Tables are presented which show the resistance to pulling when driven five inches; the weight required to drive twenty-penny cut nails for each one-quarter inch of length; weight required to pull twenty-penny cut nails each one-quarter inch in depth; the same in regard to wire nails, and also table showing driving and pulling force for cut and wire nails of ten-, eight-and six-penny size.

RAILROADS OF THE UNITED STATES IN 1894.

The Engineering and Mining Journal gives the following very satisfactory abstract of the condition and operations of the railroads of the United States from the Seventh Statistical Report of the Interstate Commerce Commission for the year ending June 30, 1894:

In the introduction to the report especial attention is called to the peculiar conditions affecting the operation of railways during the year covered by the report. (1) The report covers the last four months of the Columbian Exposition, during which time there was an increased passenger traffic. (2) It covers a period of widespread and unprecedented business depression. (3) At the close of the year, 192 roads, operating upwards of 42,000 miles of line and representing about one-fourth of the total railway capitalization, were in the hands of receivers. The effect of these conditions is apparent in nearly all of the figures presented.

The total railway mileage in the United States on June 30, 1894, was 178,708, an increase during the year of 2,247 miles. The increase during the previous year was 4,897 miles. The total number of railway employés was 779,608, a decrease, as compared with the number on June 30, 1893, of 93,994, or 10·76 per cent.

The total amount of reported railway capital on June 30, 1894, was $10,796,473,813, or $62,951 per mile of line. This is an increase in the amount outstanding during the year of $290,238,403. The amount of capital stock was $4,834,075,659, of which $4,103,584,166 was common stock, and $730,491,493 was preferred stock. The funded debt was $5,356,583,019, classified as follows: Bonds, $4,593,931,754; miscellaneous obligations, $456,277,380; income bonds, $242,403,681, and equipment trust obligations, $63,970,204. The amount of current liabilities was $605,815,135. The amount of railway securities held by railway companies as an investment was $1,544,058,670, a decrease during the year of $18,-963,563.

The amount of stock paying no dividend was $3,066,150,094, or 63·43 per cent. of the total amount. Of the stock paying dividends, 4·31 per cent. of the total stock paid from 4 to 5 per cent.; 10·12 per cent. paid from 5 to 6 per cent.; 5·12 per cent. paid from 6 to 7 per cent., and 5·42 per cent. paid from 7 to 8 per cent. The total amount of dividends was $95,575,976, or an average rate on the dividend-paying stock of 5·41 per cent. The amount of bonds paying no interest was $650,573,789, or 14·17 per cent. The amount of miscellaneous obligations paying no interest was $53,426,264, or 11·71 per cent., and the amount of income bonds paying no interest was $210,757,554 or 86·94 per cent.

The gross earnings of the railways for the year ending June 30, 1894, were $1,073,361,797, a decrease as compared with the previous year of $147,-390,077, or 12·07 per cent. Passenger revenue decreased $16,142,258, or 5·35 per cent, and the revenue from freight traffic decreased $129,562,948, or 15·63 per cent. The amount of operating expenses was $731,414,322, a decrease of $96,506,977, or 11·66 per cent. The largest decrease was in the operating expenses assigned to maintenance of way and structures and to maintenance of equipment. The net earnings were $341,947,475, a decrease of $50,883,100 as compared with the previous year. The income derived from sources outside of operations was $142,816,805. The amount of fixed charges and other deductions from income was $429,008,310, leaving a net income of $55,755,970 available for dividends, a decrease as compared with the previous year of nearly 50 per cent. The amount of dividends paid was $95,575,976, a decrease of only $5,353,909 from the amount paid the previous year. The fact that nearly the normal amount of dividends was paid notwithstanding the great decrease in income available for them, and that the payment of the amount stated entailed a deficit from the operations of the year of $45,912,044, is suggestive. The revenue derived from the carrying of passengers was $285,349,558, or 26·58 per cent. of gross earnings, and the revenue derived from freight traffic was $699,490,913, or 65·16 per cent. of gross earnings.

During the year 1,823 railway employés were killed and 23,422 were injured, as compared with 2,727 killed and 31,729 injured in 1893. To show the ratio of casualty, it may be stated that one employé was killed out of every 428 in service, and one injured out of every thirty-three employed. The trainmen perform the most dangerous service, one out of

every 156 employed having been killed and one out of every twelve having been injured.

The ratio of casualty to passengers is in striking contrast to that of railway employés, one passenger having been killed out of each 1,912,618 carried, or for each 44,103,228 miles travelled, and one injured out of each 204,248 carried, or for each 4,709,771 miles travelled.

According to the 1895 edition of "Poor's Manual of Railroads," just published, the length of track laid in the United States up to December 31, 1894, was 179,279·34 miles. The net increase of mileage of all railroads in the United States in the calendar year 1894 was 1,821·38 miles. There was a total revenue train mileage in operation in 1894 of 881,332,712 miles, including passenger, freight and elevated railroad traffic. Compared with 1893, the gross earnings of the railroads decreased in 1894 $142,313,275, to which decrease the elevated railroads contributed only $1,315,290. The total liabilities of the railroad companies at the close of 1894 were $11,565,600,207, and the total assets $11,924,450,884, leaving an excess of assets over liabilities of $358,850,677.

DETERMINING THE QUALITY OF BRASS BY COLOR.

So long as anything has been known as to the nature of the alloy of copper and zinc, certain distinctive colors have been associated with certain classes of brass. No attempt, however, has hitherto been made to distinguish the minute gradations of shade corresponding to slight modifications in the percentage composition, or to apply these variations systematically to any practical use. At a recent meeting of the British Society of Chemical Industry, Walter G. McMillan read a paper quoted in a London plumbing journal, in which he described a system which he devised about a year ago, by means of which it is possible to form an approximately accurate opinion of the composition of any given sample of brass, merely by observing the color of drillings or shavings prepared from the sample. In order to effect this satisfactorily it is necessary to have at hand a set of sealed glass tubes containing drillings of brass of known composition. With these standard drillings the drillings of any sample whose composition is desired to be known are compared. When the color of the sample is matched with that of a standard tube it is warrantable to assume that the known composition of the standard is approximately that of the sample. In this way the quality of any sample of brass may be rapidly determined by any buyer or user who is not color-blind and is possessed of average intelligence, thus avoiding the expense, labor and expenditure of time which would be occasioned if the sample had to be analysed.—*Iron Age*.

BRITISH MINERAL STATISTICS FOR 1894.

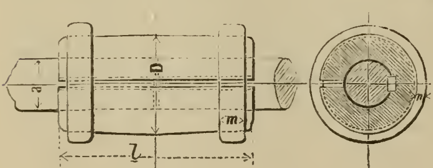
For comparison with the figures of the Mineral Statistics of the United States for the same period, published in the impression of the *Journal* for July, 1895, the following official data are from the annual *Mineral Statistics* of the United Kingdom for the year 1894: The production of coal in the United Kingdom

last year was 188,277,525 gross tons, against 164,325,795 tons in 1893, an increase of 23,951,730 tons. The year 1893 was, however, a year of serious strikes in the coal trade, from which 1894 was measurably exempt. The production of 1894 was the largest ever attained in the history of the British coal industry. The production of iron ore in 1894 was 12,367,308 tons, against 11,203,476 tons in 1893, an increase of 1,163,832 tons. The imports of iron ore into the United Kingdom in 1894 amounted to 4,413,652 gross tons, against 4,065,864 tons in 1893, an increase of 347,788 tons. The production of pig iron in the United Kingdom in 1894 was 7,427,342 tons, against 6,976,990 tons in 1893, an increase of 450,352 tons. The production of tin ore in 1894 was 12,910 tons, against 13,689 tons in 1893, a decrease of 779 tons. The production of block tin from domestic tin ore in 1894 was 8,327 tons, against 8,838 tons in 1893, a decrease of 511 tons. The imports of tin ore in 1894 amounted to 4,437 gross tons, against 3,040 tons in 1893, an increase of 1,397 tons. The imports of block tin in 1894 amounted to 39,147 tons, against 33,558 tons in 1893, an increase of 5,589 tons. It may be useful for those interested in the American tin plate industry to learn that the United Kingdom imports more than four times as much block tin as it produces, and if allowance be made for the block tin smelted from imported tin ore, its importations of block tin from other countries are five times as large as the domestic production.

A SIMPLE AND EFFECTIVE SHAFT COUPLING.

Mr. John H. Cooper contributes to *Power and Transmission* an interesting mechanical item, of which we make the following abstract:

This coupling, shown by accompanying cut, is a plain sleeve of cast iron, made slightly conical both ways from its center, and upon which two wrought-iron bands are driven. It is cut through and through on one side to the bore, which permits a slight opening and closing of the same, within the elastic limit of the metal. The key-way is cut parallel the whole length of the coupling, and directly opposite to the line of separation; it is done at the one setting in the planer. The bands are preferably of wrought iron, bored to fit the cone of the coupling, and are driven on by a "set" to the desired tightness, sufficiently to firmly close the body of the coupling upon the ends of the shafts to be joined.



It consists of a single piece of metal, without flanges, and requires no bolts to hold it together; nor has it any projecting parts, liable to catch belts or ropes or the loose garments of men.

It closes with a holding grip (being bored slightly smaller) upon each end of the coupled shafts, and may readily be removed and replaced without disturbing shafts, or bearing, or vitiating its fit or finish. It may be made very light or very heavy for any required service; short or long, according to space at disposal for it; may be

polished or not, according to taste or the style of the shafting, pulleys and hangers.

It requires neither special tools nor superior workmanship to make, to put it on or to take it off the shafts. It can be duplicated to any extent with certainty of an effective fit, which is more than can be said of the bolted "plate" coupling. It goes to its place without specially fitted keys for driving, as required by the "plate" and other solid couplings; it adapts itself to slight differences of shaft diameter, such as are incidental to shaft turning, and it "stays put" when the bands are driven "home."

The proportions for ordinary service may be summed up in the following: The total length and the middle diameter of the body, the width and the thickness of the bands are to be made, respectively: four times; double; one-half and one-fourth of the nominal diameter of the shaft.

With careful moulding and lathe centering, and for ordinary painted work, the coupling body need not be turned on the outside or ends, and for this style the bands may be cast of steel or best malleable iron, and used without turning or polish; but may be of wrought iron, turned or not, according to character of forging and exactness of finish wanted. In this decision, the only machine work necessary would be the boring, which, for any and every style of coupling, must be truly cylindrical and straight, and which, for this coupling, may be a trifle smaller than the shafts.

The cut through one side may be of the same width as the key-way, for economy of tools and time, but there is no objection to the least width that will permit grip upon the shafts. The key-way opposite may be made to suit the proportions already adopted by any shop. The intention here is to use parallel keys of uniform square section.

Some styles of couplings rust fast, and are, in consequence, difficult of removal. There is no such trouble with these; a wedge driven into the separation, after the bands are off, will free them at once.

Mr. Cooper, speaking of this coupling, says:

"I have applied these couplings where other first-class types have failed not without some misgivings, however, until full trial was past, when they proved themselves of superior holding ability.

"The philosophy of their firmness in holding is simple enough when one considers the efficiency of a band of wrought iron in direct tension. The simplest remedy for a broken thing is to shrink a wrought iron band upon it, which, in many cases, makes it stronger than it was before. This is readily admitted on the fact of the low tensile strength of cast iron, as compared with that of wrought iron, especially when the latter is under better conditions for resisting rupture.

"I began making these couplings about thirty years ago, and have since used them in every place that offered, and always with good results. Millwrights like them because they are so easy to apply and remove. First-class tool and shafting builders are making them now, which I regard as ample proof that every required dependence can be placed upon them. They have been made to couple two sizes of shafts, also cut apart longitudinally into two equal halves. In unusual cases I have made them with bolts for draw-

ing the bands on, holding them in position, and then with inside nuts on the bolts, to be used for forcing the bands asunder when uncoupling became necessary. In close quarters, where the hammer cannot be used, the bolting method answers well."

BOOK NOTICES.

Steam and the Marine Steam Engine. By John Yeo, Fleet Engineer, Royal Navy, etc. London and New York: Macmillan & Co. (Price $2.50.)

The author, being instructor in steam and marine engineering at the British Naval College, gives, in the above work, a condensed abstract of the course of instruction at this renowned institution. Treating chiefly of matters pertaining to naval construction, it is most valuable to naval officers and engineers, but should also be useful to those interested in the mercantile marine and students of engineering generally. To treat so large a subject within so small a volume is by no means easy, and the author must be complimented upon the manner in which he has given the history of the subject and the scientific principles of the same, in brief but concise outlines, at the same time describing and illustrating a number of important details. Without wasting any time and space on antiquated styles and constructions, he proceeds at once to give general outline sketches and very neat detail plans of the most modern styles of engines and boilers now in use on naval vessels, not omitting the most important forms of water tube boilers now in use; also paying some attention to valve gear, indicator diagrams, etc.

In the chapters devoted to heat, principles, properties and efficiency of steam, these important matters are treated with a simplicity and absence of complicated formulas which should make them plain to the ordinary engineer, and will even be welcome to many designers and constructors, who, in the routine of their practical career, may have grown a little rusty in the higher mathematics.

The chapters on boiler preservation, combustion of fuel, etc. contain valuable information which is generally not found in books, and the chapter treating on propulsion and propellers (although based on the antiquated and only approximate theory, that the power varies as the cube of the speed) shows clearly, by description and a number of examples, the relations between power, speed, consumption, etc. J. H.

Elementary Lessons in Steam Machinery and the Marine Steam Engine. By Staff Engineer J. Langmaid and Engineer H. Gaisford. Macmillan & Co., London and New York. (Price, $2.)

This little book was prepared for the Naval Cadets on H. M. S. *Britannia*, and forms an admirable course of preparatory instruction, laying a sound basis in the elements of construction and mechanism, on which to build up, by a more thorough study, combined with practical experience on board ship

and workshop duty ashore, a thorough knowledge of marine engine construction and management.

Beginning with a chapter on exact measurements, also giving terms of forces acting on the materials used in construction, the latter and their treatment are next described, followed by details of machinery and boilers, their principles, construction and appendages. One very useful illustration shows a cylinder and valve-chest, with movable piston and valve, enabling the student to follow the movements and relative positions of these important parts at every point. A complete description and illustration of the engines of the cruisers *Sappho* and *Scylla* is given, and the book closes with a short description of a battleship.

The book is very well printed, on excellent paper, the engravings being on separate pages, and well executed.

This work may also be useful and interesting to non-professional readers, who wish to gain a general knowledge on the subject. J. H.

Encyclopédie Scientifique des Aide-Mémoire. Sous la direction de M. Leauté, Membre de l'Institut (Section de l'Ingénieurs). Paris: Gauthier-Villars et Fils et G. Masson.

The following additional volumes of this technical series have appeared since our last notice. For general description of the scope and objects of this publication, the reader is referred to earlier notices. All volumes are uniform in size (small 8vo), and each is an independent treatise on the subject to which it relates. W.

Hennebert. Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint-Cyr, etc.—*Bouches à feu.*

Caspari, E. Ingénieur hydrographe de la Marine.—*Les chronomètres de marine.*

Dariès, G. Conducteur des Ponts et Chaussées, attaché à la Direction des Eaux de Paris. *Cubature des terrasses et mouvement des terres.*

Hennebert. Lieutenant-Colonel du Génie, ancien Elève de l'École Polytechnique.—*Torpilles sèches.*

Vallier. Chef d'Escadron d'Artillerie, Correspondant de l'Institut.—*La Balistique extérieure.*

Sidersky, D. Ingénieur chimiste.—Polarisation et saccharimétrie.

A Manual of Marine Engineering. By A. E. Seaton. Twelfth edition. London: Charles Griffin & Co., Lim. New York: D. Van Nostrand Co. (Price, $6.)

Mr. Seaton's book, when first published, was at once accepted as a standard work, and its successive editions have confirmed its claim to pre-eminence by keeping abreast of the latest developments in marine propulsion, extraordinary as they have been during the last twenty-five years. When we

consider that pressures in marine boilers have increased from 60 to 200 pounds, and piston speeds from 400 to 1,000 feet per minute, reducing coal consumption from 3 to 1¼ pounds per horse-power per hour, and increasing the horse-power attainable from a square foot of grate from 5 to 20, we can realise the enormous gain in economy of fuel, in space and weight for machinery, which enables our ocean greyhounds to cross the Atlantic at a speed of 22 knots per hour. In naval construction these developments have resulted in an increase of offensive and defensive power, which is at once apparent by comparing the battleship of to-day with the first ironclads built thirty years ago.

To introduce and develop these changes required constant advance in design, materials, methods, etc., which could only be appreciated and followed up by an engineer in constant touch with the practical application of these new principles.

That Mr. Seaton has fully realised this is very evident from the present edition, as, by comparing it with former ones, we find most of the chapters modified and extended, some entirely rewritten, a great many new illustrations added, others replaced by more modern ones, and a great deal of new text, with new illustrations, showing the very latest developments.

Thus, in former editions, triple and quadruple expansion engines were treated very briefly, and only general outline plans of them were given in an appendix, while in the present edition they are recognised as the standard types, and their theory, general construction and details fully elaborated and illustrated, while other types, which in former editions were spoken of in the present tense, are now only briefly alluded to in the past tense, showing that they have become obsolete.

Without the use of complicated formulas, or higher mathematics, Mr. Seaton shows very plainly, step by step, how the economy of compound, triple and quadruple expansion engines is obtained, both by the use of higher pressures and by successive steps in expanding steam in two or more cylinders, adding examples and a number of tables derived from practical construction. In further chapters all the details are successively treated, with formulas, examples and tables for their proper proportion and construction.

In Chapters 17 and 18, the theory of boilers and their design is treated, and a number of new illustrations and tables have been added here. Chapter 19, treating of water-tube boilers, is entirely new, and this type, now becoming more important, is described at length, with numerous fine illustrations. Of special interest to American engineers may be noted that Col. Stevens, of Hoboken, is mentioned as one of the first to construct and work successfully a water-tube boiler as early as 1805, and many may have seen this curious relic, in connection with machinery for a twin-screw boat, at some of the exhibitions held lately. Among other boilers of this type, the Herreshoff and the Babcock and Wilcox are described and illustrated; also, the Belleville, fitted in many French steamers, in the Great Northern Company's large passenger steamers on the lakes, and in the latest British cruisers *Powerful* and *Terrible*.

The remaining chapters are devoted to details of boiler construction, their

mountings and fittings, to details of engine equipment, materials, a number of useful tables, giving weights of machinery, results of trials, and, finally, the different rules for boilers and machinery prescribed by Lloyd's Register, the British Board of Trade, etc.

All these matters are presented in an eminently practical manner, with formulas of the simplest kind, rendering this work exceedingly useful to the practical constructing engineer and his assistants in the drawing office, as well as to ship owners, consulting engineers and others in this line, who sometimes have to get outlines of ship designs, estimates, etc., at short notice. J. H.

Valve Gears for Steam Engines. By Cecil H. Peabody, Associate Professor of Steam Engineering at the Massachusetts Institute of Technology. New York: John Wiley & Sons. 1892. Pp. 128, with 33 plates. (Price, $2.50.)

The author, in the preface, clearly points out that the aim of the book "is rather to give the beginner a firm grasp of the principles and some facility in their application," than an exhaustive treatment of the many gears in use at present.

In Chapter I he describes the parts of the valve gear of a slide valve engine, and deduces the equation for the movement of the valve in terms of the constants of the gear and the movement of the crank. After explaining the use of the valve ellipse and the sinusoidal diagrams of Moll and Moutéty, the diagram proposed by Zeuner is shown to agree with the valve travel on the assumption of harmonic motion for the valve. This form of diagram is used almost entirely throughout the book, because "it is widely and favorably known, and appears to the author to be be at least as good as any other circular diagram." The events of the stroke are next traced out, together with the effects upon them of changes in various parts of the gear. Besides several problems in valve design, the equalizing of cut-off on both ends of the cylinder by means of a rocker arm is given with a few methods of valve setting.

Chapter II considers adjustable eccentrics; showing first, by means of the Zeuner diagram, the effects of turning loose eccentrics on the shaft, or changing the position of movable eccentrics giving variable lead. This naturally leads to gears for shaft governing, and, as an illustration, the Straight Line governor is shown, the Zeuner diagrams for which clearly show the results obtained by moving the eccentric across the shaft. The Armington & Sims governor is also illustrated after the shifting eccentric with constant lead is dealt with.

The first part of Chapter III contains the description and analytical discussion of Stephenson and Gooch links. Their uses and distinctive features are explained and illustrated by drawings. The latter part of the chapter shows the method for equalizing cut-off and reducing slip by means of selecting proper positions for the hanger and reverse shaft, and explains the use of a skeleton model in designing gears and determining the effects produced by changes in the different members of the motion. The skeleton model will be

found useful in this field of work, although the same thing has been accomplished with more labor by the use of the link template. The method of setting a link motion is given, together with the results of varying the position of the saddle pin, length of link, point of attachment of rods, or the position of equalised cut-off, thus putting before the student facts which will be useful in practice.

Radial gears are defined and explained in Chapter IV. The Zeuner diagram for the Walschaert gear is worked out, although for the Marshall gear the valve ellipse is used. The Joy gear is illustrated, and this, with the illustrations for the former two, gives the student an idea of the gears as they appear in practice.

Chapter V treats of the methods used to obtain early cut-off by means of an auxiliary valve working on a separate seat, or on the back of the main valve. The variation of cut-off, due to shifting the eccentric or changing the lap or clearance, is shown by means of the Zeuner diagram. The method for designing and setting a Meyer valve is given, and an arrangement of eccentrics for changing the cut-off, without altering the relative movement of the valves, is worked out and explained.

In the last chapter, drop cut-off gears are described, using as examples the Brown, Corliss, Putnam, and Gaskill gears. The action of these gears is developed and the peculiarity of their design pointed out. The use of the valve ellipse for the Corliss gear is shown, and the action of the gear, when the governor is down, is explained.

The book, as a whole, is practical, uniting with the text examples from the present practice, and although, as the author says, it does not cover or attempt to cover the whole field of valve gears, it gives the student a working knowledge of the common gears, so that he may of himself be able, with little effort, to work out such gears as may present themselves. The plates in the book are of high order and illustrate fully the matter of the text. A. M. G.

Compend of Mechanical Refrigeration: A Comprehensive Digest of Applied Energetics and Thermodynamics for the Practical Use of Ice Manufacturers, Cold Storage Men, Contractors, Engineers, Brewers, Packers, and others interested in the application of Refrigeration. By J. E. Siebel, Director Zymotechnic Institute, Chicago. Chicago: H. S. Rich & Co. 1895. (Price, $2.50.)

Aside from the elaborate works on thermodynamics, treating of the scientific principles underlying the practice of mechanical refrigeration, and which are of the nature of mathematical treatises altogether too abstruse for the comprehension of those engaged in operating refrigerating machinery, the literature of this subject, at least that which is available in the English, is meager. The multiplication of uses for refrigerating machinery in ice-making, cold storage, brewing, etc., of late years has been astonishingly great, and the need for a practical treatise on the subject, which should present the various phases of the case in a manner readily adapted to the comprehension of those engaged in these industries, has been urgently felt.

The present work meets this requirement very satisfactorily. The use of mathematics has been confined to what is really necessary as a labor-saving device in making calculations, and the elucidation of the principles involved in the subject is made so clear that no intelligent engineer or manufacturer should fail to follow the author in his treatment of the subject.

The numerous physical tables and problems appended to the work add greatly to its value. W.

The Mechanical Engineers' Pocket-Book. A reference book of rules, tables, data, and formulæ, for the use of engineers, mechanics and students. By William Kent, A.M., M.E., etc. New York: John Wiley & Sons, 53 East Tenth Street. 1894. 12mo, morocco flap. (Price $5.)

Mr. Kent has given the mechanical engineering fraternity a pocket-book which will take its place as a companion volume to Trautwine's incomparable pocket-book for the civil engineer. It is thoroughly "up-to-date" and exhaustive. The publishers have done their part of the work irreproachably.

W.

The Chronicle Fire Tables for 1895.—Being a record of the fire losses in the United States and Territories during 1894, etc. Royal 8vo. New York: The Chronicle Company, Limited. (Price, $5.)

This remarkable series of tabulations comes rather later than usual, due, undoubtedly, to the increasing labor required for such work in its larger size. The fire losses of 1894, as here reported ($140,000,000), show a diminution, as compared with 1891, of $4,000,000; with 1892, of $12,000,000, and with 1893, of $28,000,000. This is cheering news to property owners and fire insurance companies. It is probably largely due to the care now insisted on by the fire underwriters' associations, and the improved supervision and inspection of risks by them and by insurance companies. It has also been aided by the much larger use of non-ignitible roofs and general improved modes of building.

This volume bears on its face evidence of that accuracy for which all its predecessors have been noted, giving, among others, an alphabetical list of fires, by causes; summary of fire losses in the United States, by causes; risks burned in said country during twenty years—1875–1894—by principal causes, besides many other valuable tabulations. The principal fires which occurred during 1894, with description of property and approximate losses, are given separately; also summaries of fires, losses and causes, by risks (148 tables), showing aggregate and average losses, proportion of fires originating on or off the premises, and causes of fires—all in alphabetical arrangement.

There is at the end, besides a full index, a valuable essay on "The Legal Status of the Insurance Agent under the Law of Agency," by the late J. Griswold, an eminent insurance expert and statistician. No wonder that the volume has swelled to 395 pages. It gives so much valuable information in

concise form, that the price should be considered low by fire insurance companies, attorneys-at-law and all careful property owners. The heavy paper, and solid, handsome binding, are all that could be desired.

N.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 16, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 16, 1895.

JOS. M. WILSON, President, in the chair.

Present, 113 members and 16 visitors.

Additions to membership since last meeting, 5.

The Secretary called attention to a circular-letter received from the Institution of Civil Engineers of London, transmitting a list of subjects for papers selected by the Council of the Institution as desirable themes for original communications, and, for meritorious contributions to which the Council is empowered to award premiums arising out of special funds bequeathed for the purpose.

Mr. Alfred F. Watch described an invention of M. Ducos du Hauron, called the Anaglyph, and which may be defined briefly as a novel photographic method of obtaining the stereoscopic effect. Mr. Watch illustrated his paper by the exhibition of a number of specimens of the work. (The paper will appear in the December impression of the *Journal.*)

Mr. W. N. Jennings exhibited and commented on a series of flash-light photographs, taken by himself in the caisson at present in use for preparing the foundation for one of the channel piers of the Delaware River bridge.

Dr. Robert Grimshaw exhibited and described a compound test indicator, made by the Bath Indicator Company, of Hyde Park, Mass.; also, an improved tool for backing-off milling cutters, the invention of Mr. S. M. Balzer, of New York; and an improved lathe tool holder, manufactured by Armstrong Brothers, of Chicago.

The Secretary presented his monthly report, an abstract of which appears in the *Journal.*

Adjourned.

WM. H. WAHL, *Secretary.*

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXL. DECEMBER, 1895. No. 6

THE FRANKLIN INSTITUTE.

Stated Meeting, October 16, 1895.

MR. JOS. M. WILSON, President, in the Chair.

THE ANAGLYPH: A NEW METHOD OF PRODUCING THE STEREOSCOPIC EFFECT.

BY MR. ALFRED F. WATCH.

The new stereoscopic pictures which I purpose showing you, and which are the invention of Mr. Ducos du Hauron, widely known from his valuable contributions to scientific photography, have, ever since their first appearance, created a great deal of interest and curiosity, and, by some, have been considered to involve the discovery of some new principle in photography. As they are printed in colors to produce the stereoscopic effect, they have been classed, by those not familiar with the manner in which they are made, among productions of chromo-photography, and it is the

object of this paper before the Institute to assign the anaglyph to its proper place among the recent discoveries, and to dispel any wrong impressions respecting these new pictures, which may have obtained currency through the publications of certain writers who have been misled by their appearance.

During the last decade, several eminent scientists and photographers have endeavored, in various ways, to produce stereoscopic pictures larger and different from the double ones, which are well known and which are viewed through a stereoscope; and some of these experimentalists—more enthusiastic than scientific—have even claimed that they could produce stereoscopic effects with prints from negatives taken from a single point of view. This claim, however, has not been proven to be correct, and doubtless never will be, as it would seem to be a physical and mathematical impossibility to realise it. The true visual stereoscopic effect can exist only where binocular vision exists. Therefore, to produce a stereoscopic effect, an object must be seen from two points of view at the same time, as is the case when those who have the use of both eyes look at an object. Each eye sees the same object from a different point, corresponding to its own position with reference to the other eye, and views it, in consequence, at a different angle. The two images on the two retinæ, blending or superimposing in the sense of vision, enable us, as the result of education and experience, to judge of the form of objects and of distances in perspectives. Therefore, to produce a stereoscopic effect in a flat picture, it is necessary so to compose it that it shall form the two distinct images which the objects depicted would produce in nature on the two retinæ of our eyes. No matter in what manner the pictures are brought before the vision, to produce stereoscopic effect two pictures are required. One of these pictures must represent the view of the right eye, and the other must represent the view of the left eye; and these two pictures, when viewed simultaneously and superimposed, produce the stereoscopic effect of binocular vision.

The "Anaglyphs," of which there are several specimens

here for your inspection, are not products of photography in colors, but simply a new kind of stereoscopic pictures, corresponding to the two images on our retinæ. They are printed, not side by side, as are the well-known stereoscopic pictures or photographs, but one over the other; thus making the prisms for their superimposition unnecessary, and making the function of the media through which they are viewed, simply that of separating the two images, and making each of them visible to that eye only, the vision of which it represents and depicts. At first thought, this would seem very difficult to do, and would seem to require very incomprehensible and complicated instruments; but when we know the principles on which the anaglyphic prints and apparatus are based, we shall find that the very simplest media—two pieces of differently colored glass—will solve the problem and reduce the blurred print into a perfect stereoscopic picture.

The whole anaglyphic process is based on two well-known facts, viz.: (1) If, through a transparent medium of some primary color, we look at an object of the same color, the object will appear almost colorless; and (2) if we look at the same object through a transparent medium of its complementary color, the object will appear almost black. By the combination of these two facts, Mr. du Hauron evolved the anaglyph.

The colors used have, for good reasons, been changed somewhat from the true complementary shades.

In the present anaglyphs, the picture corresponding to the view of the right eye is printed with *red* ink, and will appear almost black when seen through the *blue* glass, which will be in front of the right eye, when the "anaglyphoscope" is held before the eyes; but this *red* picture will be invisible to the left eye, which is covered by the *red* glass of the instrument. In like manner, the superimposed *blue* picture, which corresponds to the view of the left eye, will be visible to this eye only. Thus, each eye sees only one, its respective picture, and the two pictures, being superimposed in printing, require no prisms to produce the stereoscopic effect of binocular vision.

The instrument containing the media for looking at the these pictures (and which has been given the name "anaglyphoscope") consists principally of two pieces of plane glass of different colors, which may be mounted either in eye-glass or spectacle frames, or in boards with hoods, like the familiar stereoscopes. It makes no difference how the glasses are mounted, for, provided only that the colors are of the right quality and shade, the pictures can be seen as well through the eye-glasses, which can easily be carried, as through the hooded 'scope, although the latter possesses the advantage of shielding the eyes from extraneous light.

The anaglyphs, like the half-tones, are not entirely the products of photography, but require the aid and skill of the printer for their production; but the negatives from which the anaglyphs are produced, can be made by any amateur or professional photographer. To enable all to understand how these negatives and pictures are made, a short description of the *modus operandi* is herewith given.

As before stated, it requires two negatives to produce stereoscopic pictures. Heretofore all stereoscopic negatives and pictures have been limited to the size with which you are well acquainted, and which rarely exceeds 3½ inches each in width, because the pictures are printed side by side, and the centers or corresponding points of the pictures could not be placed much further apart than the distance between the axes of the eyes of the observer.

In the anaglyphs, the two pictures are printed one almost on top of the other, which makes it possible, therefore, to produce stereoscopic pictures the size of the largest camera or enlargement. In making these negatives, the camera is mounted on a sliding base on the tripod-head, a specimen of which is here for your inspection. The camera is placed first at one end of the slide, from which point one exposure is made; then the camera is moved along the sliding base from 3 to 9 inches to the right or left, depending on the object, and another exposure is made of the same view from this second point, and on another plate. By giving equal exposures to both plates, a pair of matched stereoscopic plates is obtained, from which the half-tone plates are made

with which the anaglyphs are printed in colored inks on the typographic press.

As stated before, the pictures are printed one over the other, not exactly superimposed, or in register, but so that one print shall be a little to the right or left of the other, the lateral edges overlapping. The two impressions are printed far enough out of register to produce the desired stereoscopic effect, and near enough to avoid double vision.

Recently, anaglyphic lantern slides and transparencies have been perfected, but I regret that, at present, I am unprepared to show them.

In conclusion, I wish to mention that the anaglyphic process can be applied also to objects and articles which are not either direct or indirect results of photography. This process is applicable, for example, to painted, woven, and stenciled articles, such as ceilings, carpets, wall-papers, floors, etc.

This process was patented August 20th of the present year, and may, in the future, find useful applications in many of the arts and industries.

DISCUSSION.

Mr. John Carbutt asked if it were not necessary to make both negatives in the same horizontal line or plane?

Mr. Watch explained that inasmuch as our eyes usually are in the same horizontal plane, the negatives should be made so. There being no parallax in the vertical direction of the human vision, two negatives for stereoscopic pictures, made from two different points of elevation, or in two different horizontal planes, would produce in the pictures the effect of vertical strabismus.

Mr. Carbutt remarked that, in one or more of the pictures exhibited, the two prints seemed to be out of register vertically as well as horizontally.

Mr. Watch explained that this was due to the careless manner in which the half-tone plates had been trimmed.

SOME PREVENTABLE WASTES OF HEAT IN THE GENERATION AND USE OF STEAM.*

By William Kent, M.E.

"Waste makes want" and "saving of waste makes wealth" are two maxims which should be remembered by every user of coal. Nearly every one is interested in saving coal: the manufacturer, to save loss or to increase his profits; the consumer of manufactured goods, in the cheapening of their price; the nation at large, in the increase of wealth. Even the miner of coal may be interested in its saving, for no amount of possible saving of coal will equal in any one year the national increase of coal consumption due to increase of population and increase of national wealth. The more saving made, the more wealth grows, the more manufactured goods are wanted and the greater the demand for coal. So, the saving of coal does not throw the poor miner out of employment, or make less coal for the railroads to carry, or less to be handled by the teamsters or others who handle it after it leaves the railroads.

Waste of coal may begin in the coal pile itself, or in the handling of it, by its crushing into dust, which may be lost. Some varieties lose some of their heating power by the influence of the atmosphere—bituminous coal mainly—anthracite very little.

Wastes in the Boiler Furnace.—The principal waste of coal in its use for making steam begins in the furnace of the steam boiler, through improper styles of furnace, or improper methods of firing.

To treat of this element of waste properly, we must first consider what coal is, and how much heat-giving power it contains; and this leads us a short distance into the discussion of its chemical constitution.

If we submit a sample of coal to proximate chemical analysis, by heating it in a crucible, we find it consists of

* A lecture delivered before the Franklin Institute.

four constituents: (1) Moisture superficially contained among its particles, and which may be driven off by a heat of 212° F.; (2) volatile combustible matter, which may be distilled by heating to a red heat in a closed retort; (3) fixed carbon, which may be burned away by heating for a long time to a bright red heat in the presence of air; (4) ash, or the incombustible residue. Take two typical samples of American coal, good anthracite and Pittsburgh bituminous, and their composition when thus analysed may be expressed about as follows:

	Anthracite. Per Cent.	*Pittsburgh. Per Cent.*
Moisture	1	1
Volatile matter	5	33
Fixed carbon	84	60
Ash	10	6
	100	100

But we may analyse these coals by another method known as ultimate analysis; and in this case we will find their chemical constituents to be as follows:

	Anthracite. Per Cent.	*Pittsburgh. Per Cent.*
Moisture	1	1
Ash	10	6
Carbon, fixed	84	60
Carbon combined with hydrogen	3	18
Hydrogen combined with carbon	1	6
Hydrogen combined with oxygen	0·1	1
Oxygen combined with hydrogen	0·8	8
Nitrogen	0·1	—
	100·0	100

The moisture, ash, nitrogen, oxygen and that portion of the hydrogen which is chemically combined with oxygen, are incombustible, and consequently are of no value as heat-giving elements, leaving as the useful materials the carbon and the remainder of the hydrogen. From scientific experiments made by European authorities, we learn what amount of heat these combustible elements are capable of giving, as follows:

1 pound of carbon burned to carbonic acid (CO_2) . 14,500 heat units.
1 " " " oxide (CO) . 4,400 "

One pound of hydrogen burned to water, (H_2O), 62,000 heat units; a heat unit being defined as the amount of heat equivalent to that required to heat 1 pound of water from 39° F. to 40° F.; that is, 1 pound of carbon thoroughly burned gives off an amount of heat, which, if entirely absorbed by water, would heat 14,500 pounds 1°.

Knowing the heat-giving power of the elements, we can now calculate the amount of heat which our two samples of coal are capable of giving off, as follows:

	Anthracite.	*Bituminous.*
C	·87 × 14,500 = 11,615	·78 × 14,500 = 11,310
H	·01 × 62 000 = 620	·06 × 62,000 = 3,720
	12,235	15,030

This gives us a measure of how much heat we should expect to obtain by burning the coals, if we could burn them thoroughly and abstract all the heat generated. But the quantity in heat units may be translated into another kind of unit more generally understood. It is found, according to the experiments of Regnault and others, that 1 pound of water at 212°, evaporated into steam at the same temperature, absorbs 966 heat units, so that 1 pound of carbon with a heating power of 14,500 heat units is capable of giving off heat sufficient to evaporate, from 212°, into steam at the same temperature, $\frac{14,500}{966} = 15$ pounds of water. This is usually expressed by saying 1 pound of carbon can theoretically evaporate 15 pounds of water from and at 212°. In a steam boiler we usually feed the water into the boiler at some other temperature than 212°, and we always evaporate the water at some higher temperature; but knowing the number of pounds evaporated per pound of coal under actual conditions of feed-water temperature and steam pressure, we can calculate, by means of steam tables published in engineering reference books, what is the equivalent evaporation from and at 212°, and comparing this with the theoretical heating value of the combustible portion of the coal, we have what is known as the efficiency of the boiler, or the percentage of heat utilised by the boiler. The difference between this and 100 per cent. is the waste heat, some

of which may be preventable, and some not preventable. For instance, suppose we had a very pure anthracite, and the heating value of 1 pound of its combustible portion was equal to 14,500 heat units, which is equivalent to 15 pounds of water evaporated from and at 212°, and we had a steam boiler which gave, in actual trial, a result equivalent to the evaporation from and at 212°, of 12 pounds of water; then the efficiency of that boiler would be $\frac{12}{15} = 80$ per cent.

Such results have actually been obtained in steam boilers in tests with good anthracite coal. At the Centennial Exhibition in 1876, thirteen boilers were tested, which, when reduced to equivalent evaporation from and at 212° per pound of combustible, gave results as follows:

No. 1	12·094
2	11·988
3	11·923
4	11·906
5	11·822
6	11·583
7	11·039
8	10·930
9	10·834
10	10·618
11	10·312
12	10·041
13	10·021

It will be noticed that the first five boilers in the list gave a result very near 12 pounds. After the fifth boiler the results decrease rapidly down to the thirteenth, which gave a result of only 10·02 pounds, or 20 per cent. less than that of the highest boilers on the list. As all of these boilers were put in the best possible condition for test, were tested with good coal and by skilled firemen, and yet gave results differing by 20 per cent., it may well be realised that in ordinary practice, with average firemen, and, in many cases, badly proportioned and badly set boilers, as well as bad types of boilers, the difference between the best practice and the worst will be very much greater than 20 per cent.

Another record of actual boiler tests, showing what may be expected in average practice, is found in a book on boiler tests recently published by Mr. George H. Barrus, of Boston. Selecting from this book, the tests of which complete records are given, with different kinds of boilers, with different firemen, with different coal and in different parts of the country, we find the results of the tests as follows:

Water Evaporated per Pound Coal.	*Number of Tests Anthracite.*	*Number of Tests Semi-Bituminous.*	*Number of Tests Bituminous.*
Over 12 pounds	—	6	—
11·5 to 12 pounds	2	6	—
11 to 11·15 pounds	10	5	—
10·5 to 11 pounds	20	3	—
10 to 10·5 pounds	11	5	1
9 to 10 pounds	14	6	2
8 to 9 pounds	8	3	—
6 to 7 pounds	1	—	—
	64	34	3

Out of sixty-four tests with anthracite coal, only two gave a result over 11·5 pounds, and, as shown in the Centennial tests, a result of 11·5 pounds was obtained with five different types of boilers, and it may be obtained with any boiler properly designed and set, fired with good coal and with a good fireman. Twenty-three out of the 64 boilers gave a result below 10 pounds, or 20 per cent. less than the highest economy attainable. In the semi-bituminous tests, only 6 boilers out of 34 gave a result of 12 pounds, which figure is not difficult to obtain with this coal in any good form of boiler properly proportioned, properly set and properly fired. From these figures, the enormous waste of coal that is continually going on in the United States in steam boiler practice, may be appreciated.

Let us now consider the causes of this waste. First, is the waste due to improper burning of the coal? In burning anthracite coal, we may have too deep a bed of coal for the amount of draught obtainable, or too little draught for the thickness of coal on the bed; and in both of these cases we will have imperfect combustion of the coal, burning a portion of the carbon to CO instead of CO_2, and obtaining from it only 4,400 heat units per pound, instead of 14,500.

This is an easily preventable waste, for this condition does not obtain to any extent if the relations of thickness of bed and of draught are such as to make the fire very hot and bright. If the fire is dull and sluggish, imperfect combustion may be suspected.

A second cause of waste is exactly the opposite of the first, namely, too much draught for the thickness of bed, or too thin a bed for the amount of draught. In Professor Johnson's report of tests made for the United States Navy, in 1844, he gives results of various tests of anthracite coal, from which we learn that the Lehigh Coal and Navigation Company's coal is by far the worst of all the anthracites. Studying closely the record of this test, we find that the reason why this coal gave such a bad result was solely because too much air was allowed to pass through the fire, and the analysis of the chimney gases showed that twice as much air was passing through the fire as is customary in the best practice. If Professor Johnson had caused still more air to pass through the fire, no doubt he would have put out the fire altogether by chilling the coal with cold air. But if, on the contrary, he had made his bed of coal on the grate twice as thick, he would have restricted the excess of air, and might have obtained the maximum result from that coal, instead of the minimum.

These two causes of waste—imperfect combustion through deficiency of air supply, and chilling the fire by excessive air supply—are usually both within the control of the fireman. No specific directions can be given which will apply in each case, and each boiler owner should, for himself, determine the best conditions of thickness of bed, method of firing, etc., which will apply in his own particular case, and make his rules of firing from his own experience.

In burning bituminous coal we meet real difficulties. As shown in our proximate analysis, by heating the coal to a dull-red heat, we drive off volatile combustible gases. In actual boiler practice, the furnace in the boiler in this way becomes a gas producer, and if the gases are driven off rapidly and at a low temperature, they are chilled by the comparatively cold surfaces of the boiler, and pass off into

the chimney unburned. In the semi-bituminous coals the waste due to this unburned gas is not so very great, since the total amount of volatile matter in the coal is usually not as much as 20 per cent. of its weight, and such volatile matter as there is in it is distilled rather slowly, and it gets a chance to burn before leaving the furnace. In all coals mined west of the Alleghenies, however, constituting the truly bituminous coals—and which are far greater in quantity than the anthracite and the semi-bituminous taken together—the volatile gases are much larger in quantity and are distilled rapidly at a low temperature, and it has not yet been found possible in average practice to prevent the escape of a large portion of these gases, with their accompanying smoke. The pall of smoke which rests over all our cities in the West is a monument to our bad engineering in not having found a way to practically utilise these gases, which are thus sent to waste. In ordinary boiler practice, with boilers as now set, all of this waste is not preventable; but that it is entirely preventable with different setting of boilers is clearly shown by the experience in steel-melting furnaces, in which the gas is first distilled in a chamber known as a gas producer, and is then carried through hot chambers of fire-brick, and heated to a high temperature, and burned with a sufficient supply of air, which has also been pre-heated by passing through similar hot chambers. With this apparatus, the gases are thoroughly burned and no smoke whatever is made. The only thing which prevents this furnace being applied to a steam boiler is the cost of construction and of maintenance. It is, however, entirely feasible, with a much simpler apparatus, to save very much of the waste gas, and prevent much of the smoke. This apparatus consists simply of a large fire-brick oven, built in front of the boiler, which serves both as a gas producer and as a combustion chamber. The conditions necessary for burning bituminous coal properly are that the gas should be heated, and that the air used to burn it should also be heated; that the combustion be carried on in intensely hot chambers; and that time enough be given for the gases and air to thoroughly intermingle before they are allowed to escape.

These conditions can be provided in a properly built oven with air-heating flues in it, but they cannot be provided in the ordinary boiler setting, because the latter does not give sufficient room.

Wastes in the Boiler Itself.—The next direction in which waste may be found in steam boilers is in the boiler itself. If it has an insufficient extent of heating surface, the gases, although properly burned in the furnace, may be allowed to pass into the chimney too hot. In ordinary stationary practice, a good rule for proportioning the heating surface is to allow 1 square foot of surface for every 3 pounds of water required to be evaporated per hour. Fifty per cent. more than this will do no harm, and may be useful in emergencies; but if less is given, excessive waste of heat in the chimney may be expected.

Another cause of waste is that, with sufficient extent of heating surface, this surface may be so placed as not to be efficient; that is, the gases may be allowed to be short-circuited, or take short passages from the furnace to the chimney, without passing uniformly over the whole extent of the heating surface. I have found this trouble in ordinary tubular boilers, in which the hot gases, after passing under the boiler, had a tendency to return through the upper rows of tubes and neglect the lower rows. In consequence, the latter were rendered ineffective, and the gases passed into the chimney at a higher temperature than if they had been compelled to sweep uniformly over the whole extent of heating surface.

Another cause of waste is the unclean condition of the boiler inside, or outside, or both. Scale on the water side of the heating surface of a boiler, and soot on the opposite side, are both non-conductors of heat, and their presence leads to waste.

The indications of waste in steam boilers are very plain; first, if the conditions of firing, draught, thickness of bed, etc., are right, there will be a very high temperature in the furnace. If there is a low temperature, either from imperfect combustion or from too great amount of air, there will be a waste, so that high temperature in the furnace is the

first condition of economy in a steam boiler. The second prime condition is low temperature in the chimney. The heat produced in the furnace must be absorbed as completely as possible by plenty of heating surface, and by clean heating surface, and by surface properly disposed so as to intercept the currents of gas, and the result will be a low temperature in the chimney. Smoke is also an indication of waste, and wherever smoke is seen, there also will be unburned combustible gases, which, as before stated, may be prevented.

Other causes of waste in steam boilers may, however, exist, coincidently with a low temperature in the chimney. One of these may be due to the passage of cold air through the rear portion of the furnace, which the fireman is very apt to leave uncovered. Another may be due to leaks of air through the setting of the boiler. This cold air absorbs heat from the furnace and boiler, and carries heat into the chimney. A third may be due to leaks of water into the furnace or flues, which abstracts heat by its evaporation, and passes into the chimney as superheated steam. Still another cause of waste, quite frequently found, is a leaky blow-off valve, as where the valve discharges into a sewer, and its leaky condition is not observed. Another cause of waste in a steam boiler, which is found in some establishments, is the waste of steam through the safety valve. In some places, where the demand for steam is irregular, but which when needed must be at a certain pressure, and the boilers are not safe to be carried at much higher pressure, the safety valves must be set at very little above the working pressure. When the work ceases for a short time steam accumulates in the boiler, and is blown off in the safety valve. The remedy for this kind of loss is to have stronger boilers, in which the pressure can be allowed to accumulate to a considerable point above the working pressure, and boilers with a large area of water level, which will allow the pumping into the boiler of a large quantity of water to absorb the excess of heat when the demand for steam is diminished, and give it out when the demand is increased. In all places where the demand for steam is irregular, great attention

should be paid to the regulation of the damper, so as to prevent fuel being wasted when the demand for steam is small. Another cause of waste in a steam boiler is too small a grate surface, causing the grates to be easily choked with clinker, and requiring more work of the fireman to keep them clean. Every time the fire is cleaned there is a waste caused by cold air rushing in the doors, and by unburned fuel being withdrawn with the clinker.

Waste Heat in the Chimney.—With a properly set boiler, running to its normal capacity, it is not usually practicable to reduce the temperature of the flue to less than 100° in excess of the temperature of the steam in the boiler, or, say, to 400° or 450°. In actual practice, 500° is more common than 400°, and in bad practice I have observed over 1,000°. But, if 400° is the lowest we can get, and the temperature of the air entering the boiler room is 80°, the hot gases leave the boiler 320° higher than the temperature of the entering air. As the temperature of the fire is not usually much above 2,000°, say, 2,400° as a maximum, the heat thus lost in the chimney is from 13 to 16 per cent. of the total heat generated by the coal. This loss is unavoidable with an ordinary boiler and chimney: first, because a moderately high temperature is necessary to make a good draught; and, second, as already stated, because we cannot reduce the temperature of the gases down to the temperature of the steam. But much of it may be saved by the use of an economiser, or set of tubes placed in the chimney, through which the feed water is passed, and heated from the entering temperature to nearly, or quite, that of the boiler. In large plants, considerable economy of heat may be had by use of these economisers, using either a very high chimney, or, better, forced draught, either blowing air in under the grate, or exhausting it out after it passes the economiser.

Wastes in Steam Piping.—We will now consider briefly some of the wastes in the use of steam, supposing that we have prevented all the wastes that we can in the steam boiler. The first waste in the use of steam is due to radiation of heat from the steam pipes. I copy the following from a published table, showing how much horse-power

may be lost from uncovered steam pipes, with the steam at 75 pounds gauge pressure:

2-inch	pipe,	1	horse-power	lost	for	every	132	feet	long.
4	"	"	1	"	"	"	"	75	"
6	"	"	1	"	"	"	"	46	"
8	"	"	1	"	"	"	"	40	"
12	"	"	1	"	"	"	"	26	"

About 90 per cent. of this waste is easily prevented by a proper covering of the pipes.

Leaks of steam from the joints and valves in steam pipes are a frequent and entirely inexcusable source of waste. Another cause of waste of the power of steam is caused by the pipes being too small and elbows too numerous, causing a serious reduction of pressure between the boiler and engine. Economising in the first cost of steam pipes and of coverings generally leads to a continual waste of heat and power.

Wastes in the Engine.—In the steam engine itself the wastes are numerous. First, there is that due to condensation of the steam as it enters the cylinder. This may cause a waste of anywhere from 10 to 50 per cent., or even more, of the whole amount of steam used. Second, there is the waste of steam in engines which are overloaded, due to exhausting the steam at too high a terminal pressure. Third, there is the waste of steam in high-pressure engines which are not loaded heavily enough, by exhausting the steam below atmospheric pressure, and requiring the engine itself to do the useless work of pushing the piston against a pressure equal to the difference between the atmospheric pressure and that of the partial vacuum behind the piston. This cause of waste becomes a very serious one in the high-pressure, non-condensing compound engine, unless special devices, such as regulation of the compression, are used to avoid it. The last two named sources of waste can be reduced to a minimum only by properly proportioning the engine to the work to be done. If the engine is to be run at a uniform load, the expansion of steam should be carried in it to such a point that the steam, when exhausted, will be at or near the back pressure in the cylinder.

Cylinder condensation has never been entirely prevented; but, as we know its causes, we can modify them to a great extent. Too short cut-off underneath involves, in high-pressure engines, expanding below the atmosphere, but also increased cylinder condensation. In high-pressure engines, therefore, we find that the maximum economy is obtained in single cylinder engines when the cut-off is between one-quarter and one-fifth of the stroke. Earlier cut-offs and later cut-offs both give worse economy. If we wish to economise steam still more than we can do in the single cylinder engine, we must use a compound engine, and, to get the maximum economy obtainable with present practice, we must expand the steam in three cylinders, beginning with steam of about 160 pounds pressure or upwards, and expanding from sixteen to twenty times.

The range of wastes in the steam engine may be understood from the following table, showing what may be expected to be the water consumed per horse-power per hour in different types of engine:

Common direct-acting pump	100	pounds	and upwards.
Old style slow-speed throttling engine, non-condensing	45	"	"
Modern high-speed automatic cut-off	30	"	"
Compound " " "	22	"	"
Corliss single cylinder high-pressure	20	"	"
" " " " condensing	18	"	"
" compound "	14	"	"
" triple-expansion condensing	12½	"	"

These figures represent about the best practice of the several types, and the word "upwards" represents any indefinitely greater amount which may be due to bad proportioning, bad setting of valves, leaks, or other causes. They show that the best triple-expansion engine will use only one-eighth of the amount of steam used by one of the worst types of engine, and less than half of the steam that is used by what is considered to be a first-class engine in ordinary stationary practice. All the consumption of steam in excess of 12½ pounds per hour per horse-power may be considered to be a preventable waste; but, as triple-expansion and compound engines are very expensive, the

interest on their cost and the increased cost of their maintenance may, in certain conditions and in certain localities, be greater than the saving in fuel. Generally, it will pay to put in a triple-expansion engine in all cases where the power required is over 500 horse-power, and the time of maximum service is more than ten hours a day. For smaller horse-powers, and for time of maximum load less than ten hours a day, it will, generally, not pay to use so expensive an engine.

Efficiency of the Steam Engine.—If we take the engine which uses only $12\frac{1}{2}$ pounds of water per horse-power per hour, and estimate that for every pound of water taken into the boiler, there is added to it 1,100 units of heat to convert it into steam of the desired pressure, this gives 13,750 heat units required per indicated horse-power per hour. As a horse-power per hour equals 1,980,000 foot-pounds of work, this, divided by 772, the mechanical equivalent of heat, gives only 2,569 heat units per hour, which, theoretically, are required to produce one horse-power. We have, therefore, as the efficiency of this engine, in relation to the heat in the steam used, $\frac{2569}{13750} = 18{\cdot}68$ per cent. If we have a boiler which gives 75 per cent. efficiency, then the combined efficiency of the boiler and engine is $18{\cdot}68 \times {\cdot}75 = 14{\cdot}01$ per cent. So that, in the best modern type of engine, we obtain only one-seventh of the heating value of the coal used; the other six-sevenths are absolute waste; but as far as our present knowledge extends, they are non-preventable. There does not seem to be any possibility of greatly reducing the waste in the steam engine, so that its consumption will be less than $12\frac{1}{2}$ pounds per hour. In all steam engines we must throw away either hot steam, as in high-pressure engines, or a vast volume of hot water, as in non-condensing engines; and in the latter case there is no known way of recovering the heat from the water that we throw away, so as to use it again in the engine. It may be left for the next century to discover some way of obtaining mechanical energy from coal without the intervention of the steam engine, but at present there seems to be no prospect

of such an invention. The preventable wastes, however, are those enormous wastes which are indicated by the difference between a consumption of $12\frac{1}{2}$ pounds per hour per horse-power, and the 25, 35, or even 100 pounds which are used in the various types of engines, and the still more inexcusable wastes which are indicated by the difference in the figures showing the best practice and the worst in steam boilers.

TECHNICAL NOTES ON THE GRAMOPHONE.*

BY EMILE BERLINER.

Professor Houston introduced the lecturer, who spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

It is the purpose of this paper to lay before you some recent experiences gathered during my work on the gramophone. It may enable future experimenters, in the field of recording and reproducing sounds, to avoid many perplexities, and at once to start into new paths of investigation, without the necessity of becoming initiated, by tedious research of their own, into the A, B, C of this new art.

Gramophony may be divided into eight principal sections: (1) The recording sound-box; (2) zinc; (3) cleaning and coating; (4) sound collectors; (5) etching; (6) the reproducing sound-box; (7) duplicating processes; (8) general features.

The Recording Sound-Box (*Figs. 1, 2* and *3*).—The diaphragm, *A*, is of mica, $\frac{5}{1000}$ inch thick, and has a free vibrating surface of $1\frac{3}{4}$ inches. A ring of blotting-paper is laid on its periphery, between the clamping surfaces of the brass sound-box, *B*. The short brass tube, *C*, to which the sound collectors are attached, is about $1\frac{1}{8}$ inches long, with a bore $\frac{11}{16}$ inch in diameter. At the inner end of this

* This paper is an elaboration of the system of gramophony, as described by Mr. Berliner, in a previous paper read by him before the Franklin Institute, and published in the *Journal*, **125**, 425.

tube a perforated cork, *D*, is inserted. This cork seems to act as a perforated diaphragm similar to the diaphragms in optical instruments, meaning thereby, that it cuts off some interfering elements of the vibrations, without impairing the strength of the effects to be attained. To the center of the mica diaphragm is fastened a thin block of hard rubber, *F*, covered with soft rubber, and a damping-spring, *G*, presses against the block, and is attached to it with wax. The free end of this spring is bent upwards. The stylus, *R*, is of steel, $\frac{2}{1000}$ inch thick, with a maximum width of $\frac{3}{8}$ inch, and its free elastic end is $\frac{1}{2}$ inch long. It is tipped with osmium-iridium, *H*, of moderately hard quality. The

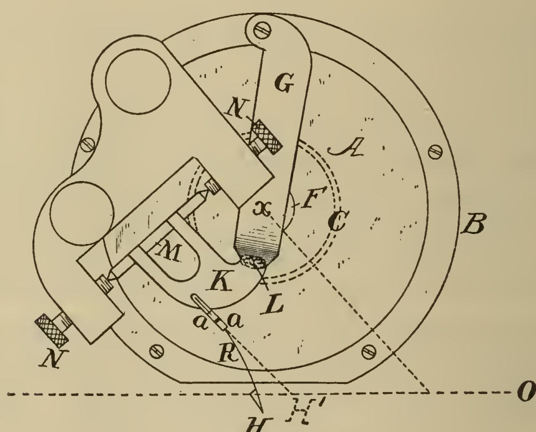

FIG. 1.

iridium is first welded to a small blade of gold, *J*, and this is soldered to the steel stylus. The iridium point is next ground down, on a fine emery wheel, to a nice point, representing a pyramid cut in two from apex to base, and dividing the base into two rectangular halves. The steel blade is inserted and soldered into the holder, *K*, of thin sheet metal, which should be as light as possible without impairing its stability, and is shaped in such a manner that the distance from the displaced center of the diaphragm to the iridium point is reduced to a practical minimum. The holder is connected to the damping spring by a mixture of shoemaker's wax and beeswax, *L*, soft or hard, according to

the season of the year. I found this method of fastening better than the finest mechanical or elastic connecting device, and it permits of easy disconnection, by a lighted match held to the wax joint, whenever it is found necessary to examine either the iridium point or the pivot, *M*. The latter is represented by a steel pin, whose hardened points are held between two adjustable screws, *N*, *N*. The adjustment must not be so loose that the stylus can fall by its own weight.

It will be seen that if, as shown in *Fig. 1*, a stylus be laid diagonally, in the writing position, across the center of a

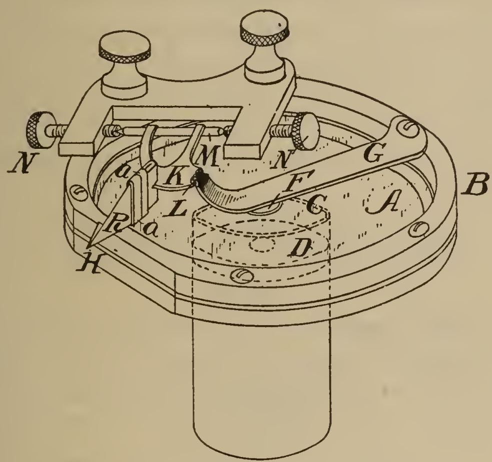

FIG. 2.

diaphragm of the same size as that used, the distance from center of diaphragm, *X*, to iridium tip, if the latter stands, say, $\frac{1}{16}$ inch over the base line, *O*, representing the zinc surface, would be about $1\frac{3}{8}$ inches; while in the present construction, in which the extended point of the damping spring is supposed to move almost parallel with the center of the diaphragm, the virtual distance, namely, that from *L* to *H*, is only $\frac{3}{4}$ inch.

The steel blade is bent downwards about $\frac{1}{4}$ inch below the working line, *i. e.*, the zinc surface, and it is straightened out when set for recording.

By modifying either of the elements of the system, some

effects become superior at the expense of others, which, of course, would have to be considered as faulty.

The wonderful mechanism of the human ear, which makes it possible for us to take notice of the scratch of a pen 10 feet away, and at the same time enables us to correctly analyse, at close proximity, the compound effects of a whole brass band, forms an ideal mechanical system, which, however, baffles all mechanical laws if we were to try to appreciate the meaning of all its internal working parts.

Speaking critically, I am aware that the resistance in the leverage in the present recording stylus, and also the friction of the iridium point against the zinc, are elements somewhat detrimental to an absolutely perfect recording of all sounds, particularly the weaker upper vibrations of low whistling, the highest register of the piano, and similar sounds. On the other hand, talking with a foreign dialect and all the characteristics of the voices of various individuals, have often been recognised without previous knowledge of the identity of the speaker; so that I am inclined to assert that the present system is fundamental in its general construction; and furthermore, that if time be taken to go back to tracing the record on glass, and to photo-engrave the same, the effects would represent the highest state of perfection and a uniform one for all sounds.

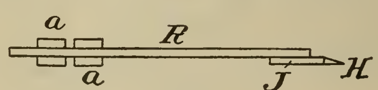

FIG. 3.

An almost perfectly working diaphragm, I have found to consist of stretched soft leather, pulled out at the center in the manner of the tympanum of the human ear; but it was inconstant in action, because the stretching would slacken it, and the substitution of soft rubber for the leather proved to be too elastic.

In soldering the iridium-tipped gold piece to the steel blade, great care must be taken not to draw the temper of the latter. When German-silver was used instead of the gold, the iridium tip was invariably too hard, and would scratch into the zinc. The reason of this I have, at one time, sup-

posed to be the difference of temperature employed for welding the iridium to the various metals, but it may have been due to the iridium itself. I have experimented with small diamond points, but they invariably scratch the zinc surface, even when the pressure of the steel blade, which generally is about 5 grams, was reduced. Tips of softer iridium, or of hardened steel, would not take hold of the zinc for any length of time with sufficient distinctness, and the result would be a rougher etching. Speaking generally, the tracing point should burnish the zinc, but not scratch it.

The present semi-hard iridium point must occasionally

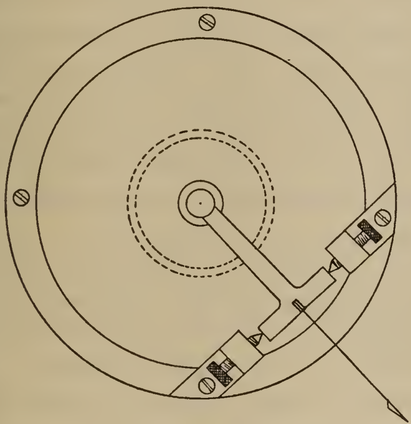

Fig. 4.

be touched up on a fine emery wheel. If glass or hard steel is employed as a register surface, a small diamond point would probably be a model tracing tip, although it might be found that the loading necessary for attaching it to the steel blade, at this, its most sensitive, point, might prove detrimental to its mechanical functions.

The steel blade is damped by two narrow, soft rubber rings, *a* and *a*, which are slipped over it as high up as possible.*

In giving these end results, some idea may be formed of

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* The system of mounting the stylus as shown in *Fig. 4* was repeatedly tried, but thus far the results have not been as good as one might expect from it.

the mass of experiments, most of them quite empirical, which were necessary for drawing the final conclusions with reference solely to the construction of the recording sound-box. Altering a single element, or proportion of parts, will somewhat modify the results, and the avoidance of errors in personal equation, as to the results obtained, has not been the least important part of the experiments. Fortunately, the field is most interesting, and the spirit of investigation is readily kept up, even after most trying interferences of unknown sources of error in the combined sections with which this paper deals.

Zinc.—Those of you who were present when I first brought the process of etching sound to public notice in this hall, will remember that, for recording-tablets, heavy discs of pure, so-called New Jersey zinc were used. I followed, at that time, the practice of the photo-engravers, and the expense of zinc discs used in experiments was considerable. Moreover, they were only roughly polished and were heavily coated with a fatty etching-ground; the results obtained were, of course, crude.

Some time afterwards, I resolved to strike out independently, and, ignoring all that had been said about impurities in commercial rolled zinc and its inadaptability to fine etching, I tried it for the gramophone.

I soon discovered some valuable points of superiority, which the common zinc had over the so-called pure zinc. It was harder, very much cheaper, could be used in much thinner discs, took a very high polish, etched more readily, retained its flatness better—being somewhat elastic—and proved itself to be in no points inferior to the pure zinc, while it resisted better the wear of the reproducing stylus.

Of course, it is advantageous to use only good Belgium, Silesian, or Illinois zinc, and it should receive the highest attainable polish.

After being polished, the discs are roughly cleaned in benzine on both sides and around the edges, and are then piled up accurately and subjected to pressure for about thirty-six hours in an ordinary letter-press, after which they will be found perfectly flat and ready for a final cleaning.

The discs have in the center a hole of the standard diameter of 7 millimeters, or $\frac{9}{32}$ inch.

Cleaning and Coating.—The disc is laid on a clean, flat and even slab, having in the center a low pin for holding the center hole. Pieces of very soft white cotton cloth (but not Canton flannel), about 2 inches square, are cut in sufficient quantities, and good benzine, gasoline, or, better yet, petroleum ether (if obtainable), is dripped on the polished face and a piece of cotton rubbed quickly and firmly over it. The rubbing is done principally in quick and short circles around the periphery of the disc. After repeating this several times and always with a fresh or turned piece of cotton, it will be found that at last the finger marks on the cotton appear, but as slight dark markings. If the zinc should accidently be softer and more easily abraded, the benzine circles under the moving fingers will quickly disappear without showing any traces, and either sign is a proof that the disc is ready for coating. This should be done at once, and the polished face should never be touched with the fingers.

Coating ought to be done in a warm and dry room, and the solution used for that purpose (which is the same fatty extract of beeswax as described in my paper before this Institute, of May 16, 1888), must be kept in a moderately warm atmosphere. In addition to this, the disc, having been fixed on a holder pushed through the center hole, is warmed over a flame, so as to appear very slightly warmer than the hand when held against the back of the disc.

The fatty extract is now poured on and off, and the last drippings are removed with a piece of cloth, while the disc is quickly dried with the breath or a handy fan. The fatty coating should then appear as a perfectly uniform, dull-looking surface, showing no bright lines or patches which would likely be subsequently etched through. The fatty film may be so thin as to appear somewhat iridescent, but not over much so, nor should it appear so dense as to be likely to offer too great a resistance to the stylus point. The coated discs may be preserved, so far as I have been able to judge, for an indefinite time, but they should be kept free from dust or handling.

Sound Collectors.—In acoustic science, the most efficient sound collectors, so far as mere loudness is concerned, are conical in shape and are of hard material. They are generally individual resonators, meaning thereby, that they enclose a column of air representing a tone of a certain pitch, which tone, when produced in close proximity thereto, will be reinforced by said air column. Hence, the smaller the column of air and the higher its pitch, the less will its reverberating, or reinforcing, effects be noticeable with ordinary sound phenomena. Furthermore, if the sides of the sound collector are of yielding, but not very elastic material, or if they are slightly perforated at many points, the individual resonance is proportionately weakened. The outer ear is both small and of yielding material, and, in a healthy state, is a sound collector neutral to all the sounds appreciable by the inner ear. It does not reinforce them, but acts as a collector and conveyor of sound, pure and simple. The column of air enclosed in a violin would resonate and reinforce its fundamental tone, were it not that the material of which a violin is made is elastic or yielding and eliminates the individual resonance.

The first telephones had large sound chambers and produced interfering sounds due to individual resonants. The harder and more unyielding the material of which a resonator is made, the more intense the reverberation of its fundamental tone; hence, the intensity of the sounds of organ-pipes, trumpets and whistles, with the application of even small air pressure.

In telephones and transmitters in which the mechanical work is infinitesimal, only small sound collectors are required, and, after a first few mistakes in telephony, no trouble was experienced in constructing them.

Not so with loud-talking machines, in which the voice is expected to do considerable mechanical work. Its whole energy, if possible, must be collected and brought to bear on the diaphragm, and this with as little inconvenience as possible to the speaker or singer.

Of all sound collectors, ordinary flexible speaking tubes, conical in extent, which, as I have found, ought to be

slightly perforated, so as to destroy the individual resonance, have been found most efficient and convenient for speaking and singing.

For instrumental music, medium-sized, but perforated funnels, of metal or hard pasteboard, *Fig. 5*, are very serviceable. For the piano, an arrangement, such as shown in *Fig. 6*, is employed. For voice and piano, or cornet and piano, a coupling, *Fig. 7*, is used. For clarionet and piano, also for band music, the arrangement shown in *Fig. 5* holds its own.

These are the principal types of sound collectors at present used by me; but experimentally, a large variety was tried, and would form quite a collection.

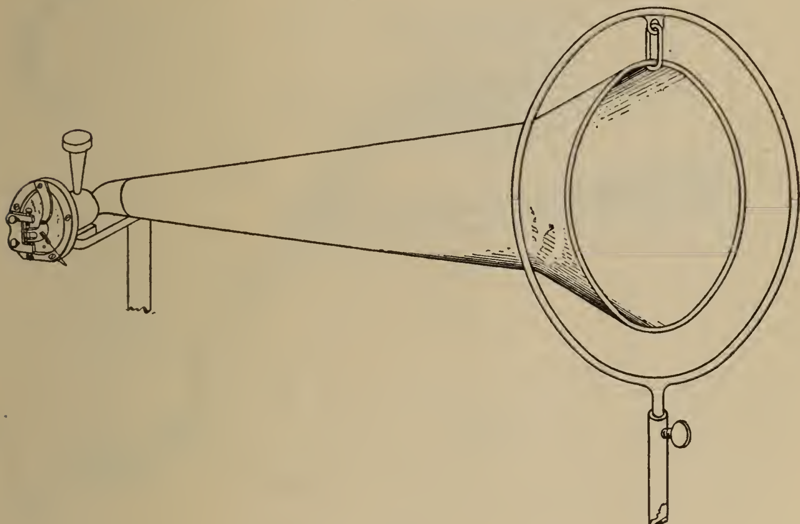

FIG. 5.

Etching.—Up to a short time ago, I used, for this purpose, commercial chromic acid, that is, the dry powder as found in the market, dissolved in water so as to form a solution of a deep wine-red color.

Lately, however, I use a liquid prepared by adding to a concentrated solution of bichromate of potash, sufficient sulphuric acid to just prevent the formation of hydrogen bubbles when dropped on zinc. This solution, I find, is

superior to the commercial chromic acid, and is very much cheaper.

In summer, the etching fluid must be kept in an ice-box, and the etching tray should be placed in a cold water bath, because considerable heat is produced during etching, and, added to that, a warm outer temperature would soften the fatty film and expose the metal to the action of the acid.

The duration of the etching process should be governed by the average amplitude of the record waves as viewed

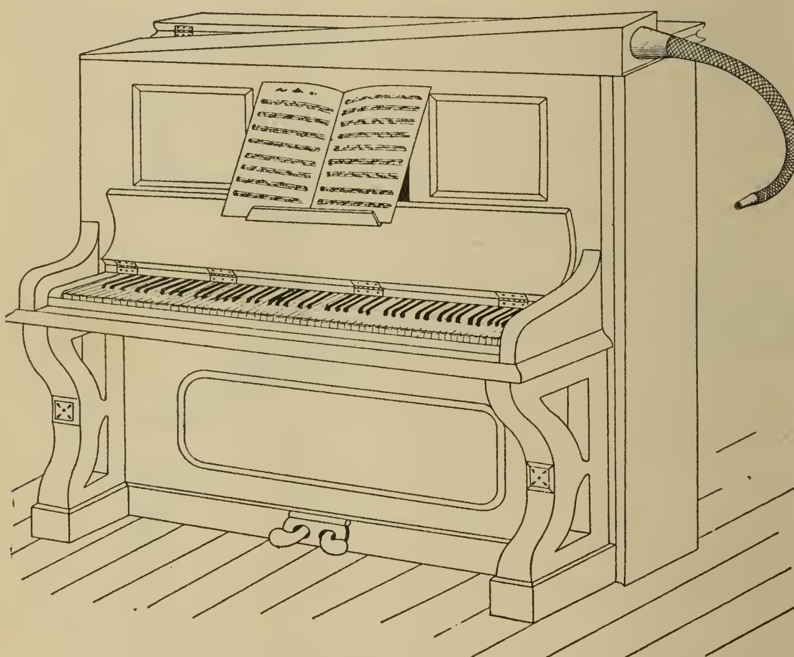

FIG. 6.

through a magnifying glass, and should be as short as possible. For ordinary conversation, and in a warm room, ten minutes is generally sufficient; for loud band effects, about twenty minutes are required. The grooves must be etched just wide enough to permit a well-pointed reproducing stylus to travel freely through the wave lines; but, if etched records are to be printed or transferred, the duration of etching must be shorter. Sound etchings on glass have been only partially successful, because the etching

ground would not withstand an acid of sufficient strength so as to make a sharp and perpendicular etching.

Etching by electricity has also been tried. The difficulty in this method was found in the electrostatic condition of the etching ground between the metal and the electrolytic fluid, which would apparently disturb its function of keeping the acid from attacking the metal.

An odd effect is produced by etching ink records with acetate of lead. The lead bushes will gradually cover the whole record ring, without, however, interfering with the etching ground underneath.

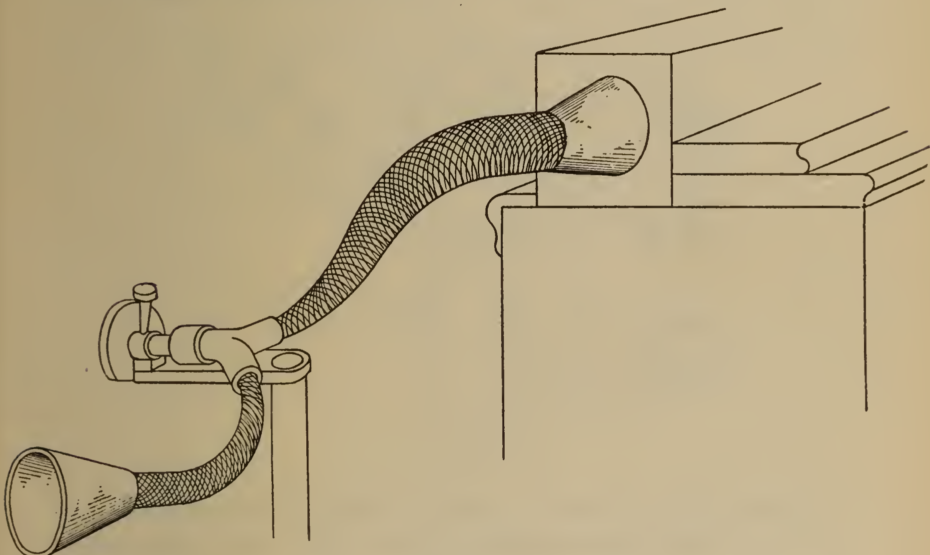

FIG. 7.

Etching has been done on hard rubber, celluloid, and the principal base metals, but zinc offers advantages over all these, and is not likely to be superseded. Polished steel would perhaps be the metal *par excellence*, but it is expensive and must be reserved for a future and more advanced state of the art.

As a side issue to gramophonic etching, a fact, important to metal-workers, was brought out in my laboratory. It was found that a solution of commercial chromic acid is the very best means for cleaning brass or copper objects.

When immersed, for from ten to thirty seconds, in such a solution, they acquire that beautiful pure surface found only in fresh electrolytic deposits. During the past year the United States Patent Office had a force of mechanics at work preparing and fixing up old models for the Columbian Fair exhibit. At a suggestion of a former assistant of mine, the office adopted the plan of cleaning with chromic acid. Entire models, often very valuable from their fine workmanship, were dipped in the solution and then washed in water and lye. The acid does not attack iron or steel, and therefore the finest bearings did not suffer.

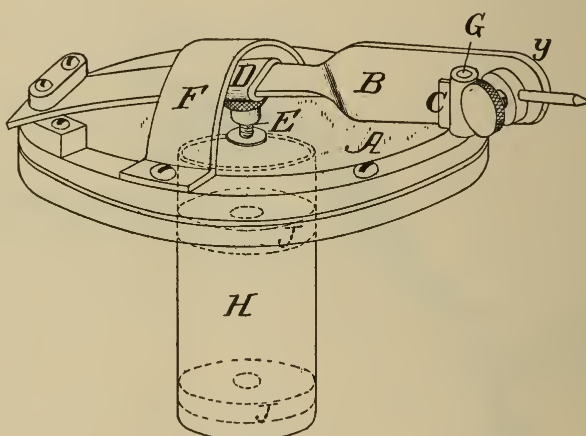

FIG. 8.

The Reproducing Sound-Box (*Figs. 8, 9, 10.*)—The diaphragm, *A*, is of extra hard German silver, $\frac{12}{1000}$ inch thick, and has a free vibrating surface of $1\frac{15}{16}$ inches. The spring stylus, *B*, which passes across the center of the diaphragm, is firmly fixed to the diaphragm box on the upper edge, and the other free end, which presses against the opposite or lower side of the diaphragm box, has just sufficient elasticity to vibrate under the impact of the etched sound vibrations.

This spring stylus has been evolved from a large number of experiments, and is both compact and efficient. It is originally, as shown in *Figs. 9* and *10*, a flat steel blade, $\frac{7}{16}$ inch wide and $\frac{1}{40}$ inch thick. It is first softened, twisted

at right angles, curved, and then again hardened, after which a blue temper is drawn in oil. In spite of its stiffness and compactness, it is a delicate part of the gramophone, and very much depends on its correct condition.

To make a first-class reproducing spring was, for a long time, largely a matter of accident, and the true inwardness of its curves, quality of steel, and mode of tempering, have been the cause of an excessive amount of experimenting. Its apparent simplicity is as misleading to the average mechanic as the production of a first-class permanent magnet is to a blacksmith.

Of the many next-to-nothings which have their say in the gramophone, the reproducing sound box has shown up

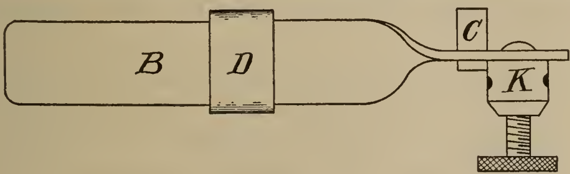

FIG. 9.

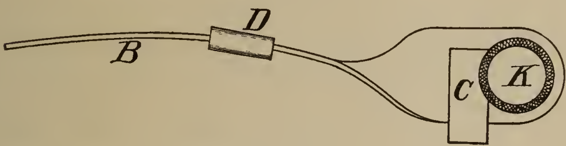

FIG. 10.

a goodly number; but they are now well known, and no difficulty is experienced in making many of like efficiency. As a matter of course, fair effects are attainable with crude apparatus, and what I state here refers to the production of the best results only.

As stated before, the spring stylus is clamped down to the upper part of the diaphragm box, and as it is originally curved, as shown in *Figs. 9* and *10*, this clamping down causes the free end, *y*, to press with considerable force against the lower part of the diaphragm box. At this point of pressure, a small metallic foot, *C*, covered with a thin soft rubber cushion, is interposed so as to give a minimum of elastic backing to the vibrations of the spring. Above the center of the diaphragm a soft rubber ring, *D*, is slipped

over the spring, and underneath it a metal sound post, *E*, which is screwed to the diaphragm, transmits the vibrations of the spring to the same. This sound post is adjustable by a screw-and-nut device, and the pressure it produces between diaphragm and spring is made to be moderately firm. The nut works stiffly on the sound post, and, besides this, the thread is waxed so as to avoid rattling. The binding post, *K*, holds a thick steel point.

A special damping device, consisting of a metal arch, *F*, and a soft rubber cushion pushed between the same and the spring, *B*, but not shown, modifies whatever outer resonance exists in the whole system of the reproducing sound box. This special damper is particularly advantageous for articulating effects, but may be left out for loud musical reproductions.

A post, *A*, partly supports the downward pressure of the stylus against the sound disc. The conveying tube, *H*, contains two perforated cork diaphragms, *J*, *J*, the functions of which are the same as the cork diaphragm in the recording sound box.

The spring stylus should stand at an angle of about 40° to the record surface, so as to permit easy action and freedom in vibrating. The needle point abrades under the continuous friction, and, when original zinc etchings are used, fresh needles must occasionally be used, so that no sharp edges may wear on the record groove. With hard rubber discs, this precaution is not vital, although a nicely rounded point of the needle often works better than a worn-off point. To correctly judge the condition of the needle point, and also for the purpose of studying records before, during, and after etching, I usually employ a lens, capable of magnifying about four diameters.

Duplicating Processes.—When I first exhibited the gramophone in this hall, I was able to show a fairly good duplicate of an original etching. This had been made by pressing the original in wax, and depositing copper on this wax mould, as is done in ordinary electrotyping. Some time afterwards a negative, that is, a plate having the lines raised instead of sunken, was made by depositing a copper shell on such an

electrotype copy. This negative was covered with electrolytic iron, or steel-faced, as it is called, and turned over to a rubber manufacturer, who, by means of this mould made some hard rubber copies by vulcanising rubber discs pressed in this negative. After further studying this over, it was found that an etched zinc plate could readily be impressed into softened hard rubber under heat and great pressure, and that, on cooling, the rubber disc had retained all the lines and marks most minutely, and represented a perfect hard-rubber negative of the original etching.

A hard-rubber negative of this character was then impressed in very hard beeswax, and, on this, copper was deposited, thereby getting a good copper mould or matrix. This matrix was then nickel-plated and rubber copies were made from this under heat and pressure.

Admirable, however, as this method would appear to be, there is a loss of surface and consequently of line work, whenever the wax became in the slightest degree softened during the mechanical part of the process, and a more direct mode of matrix-making became desirable. It was at all times evident, that if copper could be deposited directly on the original zinc plate and then lifted off, a perfect matrix should be the result. But on making the rounds among the large electrotyping firms in this country, none could be found able to do it, because none seemed to understand how to prepare a zinc plate to receive a copper deposit, without being attacked by a sulphate of copper solution. Coating the zinc plate in cyanide of copper solution proved efficient only when the copper deposit was made so thick as to affect the appearance of the zinc surface, and this meant a loss in the distinctness, or purity, of the sound from the copy discs.

It was while on a visit to Germany, that the problem was turned over to a very prominent electrotyping firm there, who succeeded, after a number of failures, in producing most accurate copper matrices by a direct deposition on zinc plates. Their method consists in covering the zinc with electrolytic brass; this is silvered and a copper shell is then deposited thereon, in a common sulphate of copper bath.

It is at best an exceedingly delicate piece of work, because, of all electrolytic solutions, the compounds of copper and zinc salts are the most fickle, and the judgment of the operator is continuously taxed to adapt his manipulation to the changing condition of the bath. Lately, however, this branch of gramophony has yielded to experience, and will soon be as easy of control as the rest of the art.

In pursuing my investigations for duplicating processes, I have had the able co-operation of your ingenious member and townsman, Mr. Max Levy, who supplied a number of missing links in our chain of research and manipulation.

General Remarks.—Thus far, the most difficult part of the gramophone work consisted in giving to the recording sound box a construction such that it would respond to, and record equally well, all kinds of sounds, from the male human voice (which is the easiest to correctly register), to the complicated effects of a duet with piano accompaniment. Many times did it become necessary to reconstruct portions of the recorder when it was found that, in a piano, for instance, the treble, or upper sounds, were brilliant and the lower ones extremely hard and jarring, or that, after a change had been made, the treble was hardly audible. A clarionet would sound all right with the exception of a single tone, which had a jarring admixture. Female voices were, for a long time, very impure in the higher notes. Then again would a baritone solo register well, but articulation was deficient and could not be readily understood. With band music, the mechanical effects on the recorder, of the various instruments, have to be carefully tested, and the players have to be placed at different distances from the recorder. Every time a change was made in a construction of a recorder, it was the occasion for a fresh series of experiments. Never in the whole course of the work was reliance placed for a certain effect on a single etching, but a number of plates were made so as to arrive at a safe conclusion, and even then fresh sources of error were often detected afterwards, either in the recording sound box, or in the sound collectors; and, in that case, all the results obtained up to that date were considered faulty, and a new

set of plates, comprising all kinds of voices and instruments, was etched, and the effects of the correction noted.

The chemical and other processes had to be continuously watched for fresh errors due to unknown causes. Once when plate after plate etched through outside of the line work, the cause was eventually traced to a greater water pressure when the alcohol was washed from the freshly traced record disc. This washing off of the alcohol originated, by the way, in a peculiar incident. You will, perhaps, remember that, in the early experiments, the disc, after the record was made on it, was placed edgewise against a support, and the alcohol dried in the air, or by fanning. One day a few drops of water accidentally fell on the wet disc and washed off the alcohol. At first it was thought that the delicate etching ground was disturbed and that the plate was spoiled; but, when it was put into the acid, that portion where the alcohol had been washed off etched faster and smoother than the other portion, and after studying it over I concluded that the alcohol dissolved a very small percentage of the fatty etching ground, and, on evaporating, would re-deposit an extremely delicate layer of fat over the traced line and thereby retard and roughen the etching. Since then every plate is washed immediately after tracing,

In the first winter season the cleaned plates would not take the etching ground readily, and the film was streaky and cloudy, and would etch through in spots. After several weeks of failure, I, at last, discovered that it was due to the fact that the room in which the plates were cleaned was much cooler than that in which they were coated, and that an invisible layer of moisture deposited on the plate by the change of temperature, and prevented the fatty film from adhering to the zinc; since then all the work is done in a well-warmed room, and the plate, which cools considerably while being cleaned with benzine, is slightly warmed over a burner before coating it with the fatty film.

Again, an iridium point would trace a poor record, and the etching was rough, and the sound harsh, and this was found to be occasioned by heating the plate too strongly in the coating process, which consolidated the fat to such an extent, that the stylus would not cut the film readily.

The reproducing machine before you is intended for discs 7 inches or less in diameter. The lines are 96 to the inch, and the diameter of the circular band, in which record lines are traced, is about $1\frac{1}{2}$ inches wide. The velocity with which a 7-inch disc should be rotated is about seventy turns a minute, so that the duration of sound on such a disc can be fully two minutes. For ordinary speaking, however, when the amplitude of vibrations is but small, the lines can be traced closer together, and a duration of three minutes for a 7-inch disc is entirely feasible.

The reproducing needle points are made of good steel, and, in the absence of special steel points, extra thick broken-off darning needles are excellent substitutes.

The reproducing sound box is compactly built, and may be placed in the hands of children without danger of becoming damaged.

Seven-inch discs can readily be mailed for a few cents all over the world, and are then protected by pasteboard from damage in transit. Should they become bent they can easily be flattened by putting them in a letter-press over night. I am carrying on a continuous correspondence by means of gramophone discs with friends across the ocean, and others have occasionally availed themselves of this means of communication. The voices of several members among my own relatives, now deceased, are thus recorded and may be recalled at any time.

Many hundreds of pounds of zinc and many gallons of acid have been used up in this work, and as each plate averaged a half an hour for its entire completion, you can readily account for the delay which the development of the gramophone has suffered. Fortunately, time was not an object, because, for its peculiar purposes of providing a cheap, durable and efficient talking machine, the gramophone, even after the delay, stands without competition, and I have been spared the spur of commercial rivalry to add to the perplexities of the situation, and could, with due leisure and caution, feel my way through the various technical problems and their labyrinthian courses.

I cannot too strongly warn future experimenters and gramophone operators against false conclusions or apparently logical tests. It is not with ordinary mechanics that talking machines deal. They are to imitate, in a coarse, mechanical way, the infinitesimal movements of the complicated inner ear, and the soft and extremely flexible motions of the vocal organs. At every new experimental step lurk the "next-to-nothings" of science, and as a training for young physicists, the technique of the gramophone should offer decided attractions.

On the GROWTH and SUSTAINING POWER of ICE.

By P. Vedel, C. E., M. West. Soc. Eng.

[*Concluded from p. 370.*]

For G and S, Thompson and Tait deduce the expressions:

$$\left.\begin{aligned} G &= A\frac{d^2 z}{d r^2} + c\frac{d z}{r\, d r} = A\left(\frac{d^2 z}{d r^2} + \frac{a}{r}\frac{d z}{d r}\right) \\ S &= A\frac{d}{d r}\nabla^2 z \end{aligned}\right\} \qquad (12)$$

whereas the bending moment around a radius is:

$$L = c\frac{d^2 z}{d r^2} + A\frac{d z}{r\, d r} = A\left(a\frac{d^2 z}{d r^2} + \frac{1}{r}\frac{d z}{d r}\right)$$

Returning now to equation (11), the exterior force Z is generally composed of the load carried by the ice, p, per square unit of its surface; the weight of the ice itself, $W \delta h$, if W is the weight of a cubic unit of water and δ the specific gravity of ice; and the upward pressure of the water on the immerged part of the ice. If the ice is floating on the water this pressure is $W \delta h + W z$; if the water has been withdrawn from under it no buoyancy can be acting; intermediate cases, where the ice is partially floating, need not be considered. Thus:

$$Z = \begin{cases} p + W \delta h \\ p - W z \end{cases} \qquad (13)$$

according as the ice is lying free or supported by the water. Inasmuch as p is considered constant, Z is in the first case independent of r.

Equation:

$$\frac{d^4 z}{d r^4} + \frac{2}{r}\frac{d^3 z}{d r^3} - \frac{1}{r^2}\frac{d^2 z}{d r^2} + \frac{1}{r^3}\frac{d z}{d r} = \frac{p + W \delta h}{A}$$

is, therefore, satisfied by the integral:

$$z = \frac{p + W \delta h}{64 A} r^4 + C r^2 \log r + C_1 r^2 + C_2 \log r + C_3 \qquad (14)$$

The more complicated equation:

$$\frac{d^4 z}{d r^4} + \frac{2}{r}\frac{d^3 z}{d r^3} - \frac{1}{r^2}\frac{d^2 z}{d r^2} + \frac{1}{r^3}\frac{d z}{d r} = \frac{p - W z}{A}$$

can only be approximately integrated. An approximation will (14) be found when p be substituted for $p + W \delta h$. A closer approximation is found by introducing for z its excess, ζ, over the ordinate of a parabola: $z_1 = d - B r^2$, where d is the maximum deflection of the ice sheet, corresponding to $r = 0$. Equating, therefore:

$$z = d - B r^2 + \zeta$$

differentiating and substituting we find:

$$\frac{d^4 \zeta}{d r^4} + \frac{2}{r}\frac{d^3 \zeta}{d r^3} - \frac{1}{r^2}\frac{d^2 \zeta}{d r^2} + \frac{1}{r^3}\frac{d \zeta}{d r} = \frac{p}{A} - \frac{W}{A}(d - B r^2) - \frac{W}{A}\zeta$$

Conceive the parabola or its parameter, B, determined so as to approach as near as possible to the actual surface of the ice sheet, then ζ will be a small quantity, and

$$\frac{W}{A}$$

being also a very small fraction, the product

$$\frac{W}{A}\zeta$$

may be neglected. But then the integral of the equation is:

$$\zeta = \frac{p - W d}{64 A} r^4 + \frac{W B}{576 A} r^6 + c r^2 \log r + c_1 r^2 + c_2 \log r + c_3$$

whence:

$$z = \frac{W B}{576 A} r^6 + \frac{p - W d}{64 A} r^4 + C r^2 \log r + C_1 r^2 + C_2 \log r + C_3 \qquad (15)$$

In these expressions, as in (14), the small and large C's designate arbitrary constants. To determine the additional constants d and B, we have the conditions that $z = d$ for $r = o$, and may, as a first approximation, assume the paraboloid of revolution to intersect the ice sheet at shore or: $d = B R^2$.

For both (14) and (15) we find:

$$C_3 = d,\ C_2 = 0.$$

The condition referring to the shearing stress gives for (14):

$$C = \frac{P}{8 \pi A}$$

and for (15) approximately the same, or in reality C perhaps a little less. By (12) the couple G is found:

$$G = \frac{p + W \delta h}{16} (3 + a) r^2 + \frac{P}{4 \pi} (1 + a) \log r + \frac{P}{8 \pi} (3 + a) + 2 C_1 A (1 + a) \qquad (16)$$

$$G = \frac{W B}{96} (5 + a) r^4 + \frac{p - W d}{16} (3 + a) r^2 + \frac{P}{4 \pi} (1 + a) \log r + \frac{P}{8 \pi} (3 + a) + 2 C_1 A (1 + a) \qquad (17)$$

and the remaining two constants, C_1 and d, are determined by the condition that expressions (14) and (16) and expressions (15) and (17) shall respectively vanish, for $r = R$.

Thus, (16) will be:

$$- G = \frac{p + W \delta h}{16} (3 + a) (R^2 - r^2) + \frac{P}{4 \pi} (1 + a) \log \frac{R}{r}$$

whereas (17) will lead to a somewhat complicated expression. Both may be simplified by substituting for a its value 0·3, whence respectively:

$$- G = 0{\cdot}21 (p + W \delta h) (R^2 - r^2) + 0{\cdot}10 P \log \frac{R}{r} \qquad (18)$$

$$- G = 0{\cdot}055\ W \frac{0{\cdot}064\ p\ R^2 + 0{\cdot}050\ P}{A + 0{\cdot}044\ W R^4} (R^4 - r^4) + 0{\cdot}21 \left(p - W R^2 \frac{0{\cdot}064\ p\ R^2 + 0{\cdot}050\ P}{A + 0{\cdot}044\ W R^4}\right) (R^2 - r^2) + 0{\cdot}10 P \log \frac{R}{r} \qquad (19)$$

To determine now the supporting power of the ice sheet, we must find the maximum value of G. But by inspection of (18) we see that no real maximum exists, but that G reaches its greatest value when r is as small as possible. Now it must be remembered that P is the sum of the weights theoretically acting in single points, circularly arranged around the center and inside the circle of radius r. The smallest possible value of r corresponding to a given P is, therefore, the radius of the circle on the circumference of which the outmost of the weights included in P are acting. $P = 0$ corresponds to $r = 0$ and the second term of (18) vanishes. In deducing our formulas we have in reality silently assumed P to be acting at or in a very short distance from the center; only then the conditions by which the arbitrary constants were determined are correct. Suppose P to be distributed over a very small circular area of radius $r = \rho$, then the greatest bending moment will be at that distance from the center, and its value G determined by (18) with ρ substituted for r.

Equation (19), on the other hand, may have a maximum or minimum. Differentiating and equating the ratio of variation of G to naught, we find:

$$\frac{r^2}{R^2} = 0{\cdot}93\left(1 - \frac{p}{W\,d}\right) \pm \sqrt{0{\cdot}86\left(1 - \frac{p}{W\,d}\right)^2 - 0{\cdot}45\,\frac{P}{W\,d\,R^2}} \qquad (20)$$

which must be < 1.

That this value of r shall not be imaginary must:

$$W\,d - p > 0$$

and

$$(W\,d - p)^2 > 0{\cdot}5233\,\frac{P\,W\,d}{R^2}$$

whence:

$$R\,(W\,d - p) > 0{\cdot}72\,\sqrt{P\,W\,d}$$

or:

$$R^8 + 1{\cdot}25\,\frac{P}{p}\,R^6 - \left(100\,\frac{A}{W} - 3{\cdot}25\,\frac{P^2}{p^2}\right) R^4 -$$

$$333{\cdot}75\,\frac{A}{W}\,\frac{P}{p}\,R^2 + \left(2500\,\frac{A}{W} - 65{\cdot}50\,\frac{P^2}{p^2}\right)\frac{A}{W} > 0 \qquad (21)$$

an equation of fourth degree in R^2 and second degree in:

$$\frac{P}{p}$$

Differentiating a second time we find

$$\frac{d^2 G}{d r^2}$$

to have the same sign as

$$44 \, W d \, \frac{r^2}{R^2} - 41 \, (W d - p)$$

which is positive or negative according as:

$$\frac{r^2}{R^2} \gtrless \frac{41}{44} \left(1 - \frac{p}{W d}\right) = 0{\cdot}93 \left(1 - \frac{p}{W d}\right)$$

The upper sign in (20), therefore, corresponds to a minimum, the lower sign to a maximum of G, and *vice versa* for $-G$. And inasmuch as G from 0, corresponding to $r = R$, decreases with r decreasing to the greater of the two values (20), then increases until r reaches the lower value (20), and then again decreases with r, the numerical maximum may correspond to the upper sign of (20) and a numerical minimum or smaller maximum to the lower sign.

If R is too small to satisfy equation (21) the same applies to (19) as to (18); G has no real maximum, but is numerically as great as possible when r is as small as possible, *i. e.*, $r = \rho$. Otherwise there is a maximum, corresponding to the value of r, determined by (20) taken with its upper or lower sign. But still the value of G corresponding to $r = \rho$ may be greater than the maximum.

With the inch and the pound as units we have:

$$W = 0{\cdot}036 \, ; \; \delta = 0{\cdot}92 \, ; \; A = 0{\cdot}09 \, M \, h^3 = 1071 \times 10^5 \, h^3$$

Reducing farther the hyperbolic logarithms to common logarithms by introducing the factor 2·30, and substituting G for the numerical value of $\mp G$, and in (18) ρ for r, we find:

$$G = (0{\cdot}21 \, p + 0{\cdot}007 \, h) \, (R^2 - \rho^2) + 0{\cdot}23 \, P \log \frac{R}{\rho} \qquad (22)$$

$$\pm G = \frac{13\,p\,R^2 + 10\,P}{1071 \times 10^{10}\,h^3 + 158\,R^4}(R^4 - r^4) +$$

$$(0{\cdot}21\,p - R^2\,\frac{48\,p\,R^2 + 38\,P}{1071 \times 10^{10}\,h^3 + 158\,R^4})\,(R^2 - r^2) +$$

$$0{\cdot}23\,P\,log\,\frac{R}{r} \qquad (23)$$

where r is either ρ or the value determined by (20).

Equations (22) and (23) determine the breaking moments which, taken per unit of length, should be equated to the moment of resistance, or $\frac{1}{6}\,Ch^2$, when C denotes the coefficient of resistance, or say 200 pounds per square inch. If, for convenience sake, R, r and ρ be expressed in feet, p in pounds per square foot, h in hundredths of inches, then we shall have:

$$h^2 - 3\,h\,(R^2 - \rho^2) - 63\,p\,(R^2 - \rho^2) - 69\,P\,log\,\frac{R}{\rho} = 0 \quad (24)$$

$$h^5 \mp (63\,p\,(R^2 - r^2) + 69\,P\,log\,\frac{R}{r})\,h^3 + 0{\cdot}3\,R^4\,h^2 \mp$$

$$(8\,p\,R^2 + 6\,P)\,(R^4 - r^4) \pm (9\,p\,R^4 + 22\,P\,R^2)\,(R^2 - r^2) \mp$$

$$21\,P\,R^4\,log\,\frac{R}{r} = 0 \qquad (25)$$

respectively for the ice-sheet unsupported or supported by the underlying water. Here r is determined by (20) or, in the adopted units:

$$1{\cdot}07\,r^2 = R^2 - k\,p \pm \sqrt{(R^2 - k\,p)^2 - 0{\cdot}52\,k\,P} \qquad (26)$$

where:

$$k = \frac{R^2}{144\,W\,d} = \frac{h^3 + 0{\cdot}31\,R^4}{0{\cdot}35\,P + 0{\cdot}45\,p\,R^2}$$

or, if this is an imaginary quantity or the corresponding value of G is numerically greater,

$$r = \rho$$

These somewhat unwieldy general expressions are considerably simplified when either

$$P = 0$$

or

$$p = 0$$

If

$$P = 0$$

then

$$\rho = 0$$

and (24), (25), (26) give :

$$h^2 - 3\,h\,R^2 - 63\,p\,R^2 = 0$$

$$p = \frac{h^2}{63\,R^2} - \frac{h}{21} \tag{27}$$

$$h^5 \mp 63\,p\,(R^2 - r^2)\,h^3 + 0{\cdot}3\,R^4\,h^2 \pm p\,R^2\,(R^4 - 9\,R^2\,r^2 + 8\,r^4) = 0$$

$$p = \pm\,\frac{h^2\,(h^3 + 0{\cdot}3\,R^4)}{63\,h^3\,(R^2 - r^2) - R^2\,(R^4 - 9\,R^2\,r^2 + 8\,r^4)} \tag{28}$$

where :

$$r^2 = \begin{cases} \dfrac{2\,(R^2 - k\,p)}{1{\cdot}07} = 0{\cdot}58\,R^2 - 4{\cdot}15\,\dfrac{h^3}{R^2} & \text{corresponding to the upper sign.} \\ 0 & \text{corresponding to the lower sign.} \end{cases}$$

if

$$h^3 < \frac{58}{415}\,R^4$$

or

$$h < 0{\cdot}52\,R\,\sqrt[3]{R}$$

and otherwise, or if the corresponding value of p is smaller

$$r = 0$$

corresponding to the upper sign ρ:

$$p = \frac{h^2\,(h^3 + 0{\cdot}3\,R^4)}{R^2\,(63\,h^3 - R^4)}$$

If, on the contrary,

$$p = 0$$

the equations will be:

$$h^2 - 3\,h\,(R^2 - \rho^2) - 69\,P\,log\,\frac{R}{\rho} = 0$$

$$P = \frac{h^2 - 3\,h\,(R^2 - \rho^2)}{69\,(log\,R - log\,\rho)} \tag{29}$$

$$h^5 \mp 69\, P \log \frac{R}{r}\, h^3 + 0{\cdot}3\, R^4\, h^2 \pm P\,(16\, R^4 - 22\, R^2\, r^2 +$$

$$6\, r^4) \mp 21\, P\, R^4 \log \frac{R}{r} = 0$$

$$P = \pm \frac{h^2\,(h^3 + 0{\cdot}3\, R^4)}{(69\, h^3 + 21\, R^4) \log \dfrac{R}{r} - (16\, R^4 - 22\, R^2 r^2 + 6\, r^4)} \qquad (30)$$

where:

$$r^2 = 0{\cdot}93\, R^2 \pm \sqrt{0{\cdot}47\, R^4 - 1{\cdot}29\, h^3}$$

if:

$$h^3 < \frac{47}{129} R^4$$

or

$$h < 0{\cdot}71\, R \sqrt[3]{R}.$$

and otherwise, or if the corresponding value of P is smaller than the geometrical minimum, $r = \rho$. The upper sign in r^2 corresponds to the upper sign of P, the lower to the lower. If the upper value of r is $> R$, it is, of course, impossible as a solution; the same if the lower value is $< \rho$. The upper sign corresponds to $r = \rho$.

Equations (27) and (29) show that when the ice is not supported by the water we must always have:

$$h > \begin{cases} 3\, R^2 \\ 3\,(R^2 - \rho^2) \end{cases}$$

respectively. In equations (28) and (30) it must be tried whether either of the two maxima or minima, or r as small as possible, *i. e.*, $r = \rho$, gives the smallest value for p or P.

Let, for illustration, these formulas be applied to the case where the diameter of the lake is $D = 2\, R = 10^n$ feet, and, when P does not vanish, $\rho = 2$ feet. Equations (27) and (29) then give:

$$p = \frac{6\, h^2}{10^{2n+2}} - \frac{5\, h}{10^2}$$

$$P = h\, \frac{h - 75 \times 10^{2n-2} + 12}{69\, n - 42}$$

Equation (28) gives:

$$p = \begin{cases} \dfrac{6\,h^2}{10^{2n+2}} \dfrac{h^3 + 188 \times 10^{4n-4}}{h^3 - 10^{4n-3}} \\ 2 \times 10^{2n-3}\,h^2 \dfrac{h^3 + 188 \times 10^{4n-4}}{h^6 + 14 \times 10^{4n-3}\,h^3 + 48 \times 10^{8n-6}} \end{cases}$$

according as

$$h \gtrless 3{\cdot}9 \times 10^{\frac{4(n-1)}{3}}$$

the second expression implying as a necessary condition that

$$h < 4{\cdot}4 \times 10^{\frac{4(n-1)}{3}}$$

but this limit being lowered by the additional condition that the smaller of the two values for p should be used.

And (30) gives:

$$P = h^2 \frac{h^3 + 188 \times 10^{4n-4}}{(69n - 42)\,h^3 + (131\,n - 179) \times 10^{4n-2} + 22 \times 10^{2n} - 96}$$

this value of P being always smaller than the one corresponding to the geometrical minimum, which is:

$$P = 372 \times 10^{8n-6}\,h^2$$

$$\times \frac{h^3 + 188 \times 10^{4n-4}}{h^9 + 135 \times 10^{4n-3}\,h^6 - 987 \times 10^{8n-5}\,h^3 + 139 \times 10^{12n-6}}$$

and only possible if

$$h < 6{\cdot}1 \times 10^{\frac{4(n-1)}{3}}$$

The following table has been calculated from these formulas and applies to ice supported by the underlying water. The thickness of the ice is indicated by H in inches instead of by h in hundredths of inches. The uniformly distributed weight per square foot has, for $n = 1$ and $n = 2$, been determined by the first of the two expressions for p, inasmuch as $h > 84$. The total uniformly distributed load $\frac{1}{4}\,\pi\,D^2\,p$ is for $n \geqq 4$ practically constant for the same thickness of ice.

TABLE I.—VALUES OF p IN POUNDS PER SQUARE FOOT AND $\frac{1}{4}\pi D^2$ AND P IN POUNDS.

D (in ft.) . .	10			100			1,000			10,000			100,000			1,000,000		
$\frac{1}{4}\pi D^2$ . . .	78·54			7,854			$7{,}854 \times 10^2$			$7{,}854 \times 10^4$			$7{,}854 \times 10^6$			$7{,}854 \times 10^8$		
n	1			2			3			4			5			6		
$3·9 \times 10^{\frac{4(n-1)}{3}}$	3·9			84			1,810			39,000			840,216			181,022,400		
H (= 0·01 h) in inch.	p	$\frac{1}{4}\pi D^2 p$	P	p	$\frac{1}{4}\pi D^2 p$	P	p	$\frac{1}{4}\pi D^2 p$	P	p	$\frac{1}{4}\pi D^2 p$	P	p	$\frac{1}{4}\pi D^2 p$	P	p	$\frac{1}{4}\pi D^2 p$	P
	$6\,H^2$.	$471·2\,H^2$	$370·37\,H^2$							$\frac{783}{10^7}H^2$	$6152·3\,H^2$	$54·49\,H^2$	$\frac{783}{10^9}H^2$	$6152·3\,H^2$	$39·50\,H^2$	$\frac{783}{10^{11}}H^2$	$6152·3\,H^2$	$30·97\,H^2$
1	6	471	370	0·19	1,500	161	0·008	6,150	88	8×10^{-5}	6,152	54	8×10^{-7}	6,152	39	8×10^{-9}	6,152	31
2	24	1,885	1,482	0·30	2,356	464	0·031	24,559	351	31 × "	24,609	218	31 × "	24,609	158	31 × "	24,609	107
3	54	4,241	3,333	0·58	4,554	972	0·070	55,017	790	71 × "	55,371	490	71 × "	55,371	355	71 × "	55 371	279
4	96	7,539	5,926	0·99	7,773	1,693	0·123	96,958	1,403	125 × "	98,437	872	125 × "	98,437	632	125 × "	98,437	496
5	150	11,780	9,259	1·52	11,968	2,608	0·190	149,336	2,165	196 × "	153,808	1,362	196 × "	153,808	987	196 × "	153,808	774
6	216	16,963	13,333	2·18	17,120	3,768	0·268	210,558	3,147	282 × "	221,483	1,962	282 × "	221,483	1,422	282 × "	221,483	1,115
7	294	23,089	18,148	2·96	23,224	5,119	0·355	278,424	4,270	384 × "	301,463	2,670	384 × "	301,463	1,936	384 × "	301,463	1,518
8	384	30,157	23,704	3·85	30,276	6,680	0·446	350,257	5.556	501 × "	393,747	3,487	501 × "	393,747	2,528	501 × "	393,747	1,982
9	485	38,167	30,000	4·87	38,274	8,449	0·539	423,032	6,998	634 × "	498,336	4,414	634 × "	498,336	3,200	634 × "	498,336	2,509
10	600	47,120	37,037	6·01	47,217	10,427	0·629	493,679	8,590	783 × "	615,230	5,449	783 × "	615,230	3,950	783 × "	615,230	3,097
11	726	57,015	44,815	7·27	57,105	12,614	0·712	559,346	10,323	947 × "	744,428	6,593	947 × "	744·428	4,780	947 × "	744,428	3,747
12	864	67,853	53,333	8·65	67,936	15,009	0·786	617,646	12,189	1,128 × "	885,931	7,847	1,128 × "	885,931	5,688	1,128 × "	885,931	4,460

Referring to the army rules, we see that actually for $D \leqq 10{,}000$ feet = about two miles, a two-inch ice sheet will safely support a man of 200 pounds weight, whereas a man on horseback, weighing, with the horse, 1,200 pounds, if this weight were acting over an area of only 4 feet diameter, would need 5-inch ice.

Ice not supported by the water, as the formulas show, cannot carry its own weight unless $h > 8 \times 10^{2n-1}$. Except for very small ponds, the ice will therefore crack and sag when the water recedes from under it.

In what precedes, we have considered the water-basin as circular, or at least approximately so. The formulas therefore apply with a fair approximation to most any lake when its average diameter is taken as D. For Lake Superior, D may be taken as 200 miles; for Lake Michigan, 180; Lake Huron, 175; Lake Erie, 113; and Lake Ontario, 97 miles. But if the ice covers a canal or a river, other formulas are required.

Considering a unit length of the canal and its ice-cover—just as we do when we calculate a retaining wall—and returning to the general equations, we deduce from (10) the equation:

$$A \frac{d^4 z}{d x^4} = Z = \begin{cases} p + W \delta h \\ p - W z \end{cases}$$

which takes the place of (11) and (13). The arbitrary constants of the integrals:

$$z = \frac{p + W \delta h}{24 A} x^4 + C x^3 + C_1 x^2 + C_2 x + C_3 \quad (31)$$

$$z = \frac{p}{W} + e^{\sqrt[4]{\frac{W}{4A}} x} \left(C \cos \sqrt[4]{\frac{W}{4A}}\, x + C_1 \sin \sqrt[4]{\frac{W}{4A}}\, x\right) +$$

$$e^{-\sqrt[4]{\frac{W}{4A}} x} \left(C_2 \cos \sqrt[4]{\frac{W}{4A}}\, x + C_3 \sin \sqrt[4]{\frac{W}{4A}}\, x\right) \quad (32)$$

where e is the base of the natural logarithms, are determined by the conditions that

$$\frac{d z}{d x} = 0, \text{ for } x = 0;$$

and

$$z = 0$$

and

$$G = A \frac{d^2 z}{d x^2} = 0$$

at shore ($x = b$); and

$$S = A \frac{d^3 z}{d x^3} = \int_0^x Z\, d x + \tfrac{1}{2} P$$

This gives for the free-lying ice:

$$C = \frac{P}{12 A}, \; C_2 = 0$$

and:

$$- G = \frac{p + W \delta h}{2} (b^2 - x^2) + \frac{P}{2} (b - x) \tag{33}$$

It gives for the water-borne ice:

$$C_2 - C = C_1 + C_3 = \frac{P}{2 W} \sqrt[4]{\frac{W}{4 A}}$$

and with γ for

$$\sqrt[4]{\frac{W}{4 A}}$$

and *Cos* x, *Sin* x for the hyperbolic functions:

$$\frac{e^x + e^{-x}}{2}$$

or $\cos \sqrt{-1}\, x$ and

$$\frac{e^x - e^{-x}}{2}$$

or $\sqrt{-1} \sin \sqrt{-1}\, x$

$$- G (\mathrm{Cos}\, 2 \gamma b + \cos 2 \gamma b) = \frac{p}{2 \gamma^2} [\mathrm{Sin}\, \gamma (b + x) \sin \gamma (b - x)$$

$$+ \sin \gamma (b + x) \mathrm{Sin}\, \gamma (b - x)] + \frac{P}{4 \gamma} [\mathrm{Cos}\, \gamma x \sin \gamma (2b - x)$$

$$- \sin \gamma x\, \mathrm{Cos}\, \gamma (2b - x) + \cos \gamma x\, \mathrm{Sin}\, \gamma (2b - x) - \mathrm{Sin}\, \gamma x \cos \gamma (2b - x)] \tag{34}$$

The greatest value of $-G$ (33) corresponds to x as small as possible, or $x = 0$ when $P = 0$, and otherwise $x = \rho$ when P covers a length 2ρ. But $-G$ (34) may have a maximum or minimum. Differentiating, remembering that

$$\frac{d\, Cos\, x}{d\, x} = Sin\, x$$

and

$$\frac{d\, Sin\, x}{d\, x} = Cos\, x$$

and equating the ratio of variation of G to naught, we find:

$$p\,[Cos\,\gamma\,(b + x)\,sin\,\gamma\,(b - x) - sin\,\gamma\,(b + x)\,Cos\,\gamma\,(b - x) + cos\,\gamma\,(b + x)\,Sin\,\gamma\,(b - x) - Sin\,\gamma\,(b + x)\,cos\,\gamma\,(b - x)] = P\,\gamma\,[Cos\,\gamma\,x\,cos\,\gamma\,(2b - x) + cos\,\gamma\,x\,Cos\,\gamma\,(2b - x)] \quad (35)$$

which determines the value of x that makes G a maximum or minimum. The numerically greatest value of G, whether corresponding to this x, or to x as small as possible, *i. e.*, $x = 0$ or $x = \rho$, should be equated to the moment of resistance $\frac{1}{6}\,C\,h^2$, or

$$\frac{200}{6}\,h^2.$$

if h is expressed in inches.

With (as before) $W = 0{\cdot}036$, $\delta = 0{\cdot}92$, $A = 1071 \times 10^5\,h^3$, equation (33) gives:

$$h^2 - 7h\,(b^2 - \rho^2) - 150\,p\,(b^2 - \rho^2) - 150\,P\,(b - \rho) = 0 \quad (36)$$

where P is expressed in pounds per linear foot, p in pounds per square foot, b, x, ρ in feet, and h in hundredths of inches. In (34) and (35) is, with the same units:

$$\gamma = \frac{1}{10{\cdot}44\,h^{\frac{3}{4}}}$$

and for $\gamma\,x$ or $\gamma\,b$ to substitute

$$\frac{1{\cdot}15\,x}{h^{\frac{3}{4}}}$$

or

$$\frac{1{\cdot}15\,b}{h^{\frac{3}{4}}}$$

and for P and p to substitute

$$\frac{P}{12}$$

and

$$\frac{p}{144}.$$

G is to be equated to:

$$\frac{1}{300}h^2$$

But it is unnecessary to reproduce the complicated equation thus deduced. In any particular case the approximate solution of (34) and (35) will offer no great difficulty when, simultaneously with the tables of the circular functions, those of the hyperbolic functions are consulted. Such tables have been published by Ligowski and others, and are to be found in Hütte: "Des Ingenieurs Taschenbuch."

If either $P = 0$ or $p = 0$, equation (36) gives:

$$h^2 - 7\,h\,b^2 - 150\,p\,b^2 = 0$$

and

$$h^2 - 7\,h\,(b^2 - \rho^2) - 1800\,P\,(b - \rho) = 0$$

The ice, when not supported by the water, must, therefore, always have a thickness:

$$h > 7\,b^2$$

or

$$> 7\,(b^2 - \rho^2)$$

respectively.

Equation (35) gives, with γ_1 for

$$\frac{1{\cdot}15}{h^{\frac{3}{4}}}$$

$$Cos\,\gamma_1\,(b + x)\,sin\,\gamma_1\,(b - x) + cos\,\gamma_1\,(b + x)\,Sin\,\gamma_1\,(b - x) =$$
$$Sin\,\gamma_1\,(b + x)\,cos\,\gamma_1\,(b - x) + sin\,\gamma_1\,(b + x)\,Cos\,\gamma_1\,(b - x)$$

and

$$Cos\,\gamma_1\,x\,cos\,\gamma_1\,(2\,b - x) = -\,cos\,\gamma_1\,x\,Cos\,\gamma_1\,(2\,b - x)$$

or, with $Tg\,x$ for

$$\frac{Sin\,x}{Cos\,x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$$Tg\,\gamma_1\,x\,(Tg\,\gamma_1\,b\,tg\,\gamma_1\,b - 1) = tg\,\gamma_1\,x\,(Tg\,\gamma_1\,b\,tg\,\gamma_1\,b + 1) \quad (37)$$

$$Sin\,2\,\gamma_1\,b\,Tg\,\gamma_1\,x - sin\,2\,\gamma_1\,b\,tg\,\gamma_1\,x = Cos\,2\,\gamma_1\,b + cos\,2\,\gamma_1\,b \quad (38)$$

And (34), equated to

$$\frac{1}{300}\,h^2$$

gives:

$$h^{\frac{1}{2}} = \pm\,228\,p$$

$$\frac{Cos\,\gamma_1 b.\,cos\,\gamma_1\,b.\,Cos\,\gamma_1\,x.\,cos\,\gamma_1\,x(Tg\,\gamma_1\,b.\,tg\,\gamma_1\,b - Tg\,\gamma_1\,x.\,tg\,\gamma_1\,x)}{Cos\,2\,\gamma_1\,b + cos\,2\,\gamma_1\,b} \quad (39)$$

$$h^{\frac{5}{4}} = \pm\,65\,P.\,Cos\,\gamma_1\,x.\,cos\,\gamma_1\,x$$

$$\left[\frac{Sin\,2\,\gamma_1\,b + sin\,2\,\gamma_1\,b + Tg\,\gamma_1\,x.\,tg\,\gamma_1\,x\,(Sin\,2\,\gamma_1\,b - sin\,2\,\gamma_1\,b)}{Cos\,2\,\gamma_1\,b + cos\,2\,\gamma_1\,b} - Tg\,\gamma_1\,x - tg\,\gamma_1\,x\right] \quad (40)$$

where it should be remembered that γ_1 contains h, and x, which must always be $< b$ and $\geqq 0$ or ρ, is either determined by (37), (38) or equal to 0 or ρ, according to which of these values makes the term on the right hand side of (39), (40) numerically as great as possible.

Equation (37) gives no possible solution when b is so small that

$$\gamma_1 b < \frac{\pi}{2}$$

and consequently

$$\gamma_1\,x \text{ also} < \frac{\pi}{2}$$

for the circular tangent is then greater than the hyperbolic tangent. But when $\gamma_1\,b$ is approximately equal to or greater than 2, the hyperbolic tangent is very nearly equal to 1; and as $\gamma_1\,x$ must be

$$> \frac{\pi}{2}$$

if (37) shall have any solution, we have:

$$Tg\,\gamma_1\,x = Tg\,\gamma_1\,b = 1$$

and consequently

$$tg\,\gamma_1\,x = \frac{tg\,\gamma_1\,b - 1}{tg\,\gamma_1\,b + 1}$$

$$\gamma_1\,x = \gamma_1\,b - \frac{\pi}{4} - n\,\pi$$

where n is an arbitrary, positive ($x < b$), whole number. In (39) only $Cos\,\gamma_1\,x$ varies numerically with n, decreasing with it; that the right-hand side of the equation may be as great as possible, we must, therefore, make $n = 0$*. Thus, $2\,\gamma_1 b > 4.7$.

But for the hyperbolic functions we have approximately:

$$Cos\,\varphi = Sin\,\varphi = \tfrac{1}{2}\,e^{\varphi}$$

when $\varphi > 2$ and almost exactly when $\varphi > 5$.

Hence, (39), with, for simplicity's sake, H for $0.01\;h$, may be transformed to:

$$H^{\frac{1}{2}} = 8\,p\;\frac{Cos'\left(\gamma_1 b - \frac{\pi}{4}\right)}{Cos\,\gamma_1\,b}$$

or

$$p = \frac{\sqrt{H}}{8}\;\frac{Cos\,\gamma_1\,b}{Cos\left(\gamma_1 b - \frac{\pi}{4}\right)}$$

or, approximately, when $\gamma_1\,b$ is great:

$$p = \frac{\sqrt{H}}{8}\,e^{\frac{\pi}{4}} = 0.271\;\sqrt{H} \qquad (41)$$

This value, to which p converges when $\gamma_1\,b$ increases, is independent of b.

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* To other values of n correspond other maxima or minima of G, but relatively smaller. The corresponding x determines dangerous points where breaks might occur.

To $x = 0$ corresponds:

$$p = \frac{\sqrt{H}}{23} \frac{Cos\, 2\,\gamma_1\, b + cos\, 2\,\gamma_1\, b}{Sin\,\gamma_1\, b\, sin\,\gamma_1\, b} \tag{42}$$

or, approximately, when $\gamma_1 b$ is great:

$$p = \frac{\sqrt{H}}{23} \frac{Sin\,\gamma_1\, b}{sin\,\gamma_1\, b} = 0{\cdot}044 \sqrt{H} \frac{Sin\,\gamma_1\, b}{sin\,\gamma_1\, b}$$

which, for $\gamma_1\, b > 2{\cdot}25$, is greater than (41), and, therefore, inapplicable.

Equation (38) gives no possible solution when

$$2\,\gamma_1\, b < \frac{\pi}{2}$$

because *Cos* is always > *Sin* and $T\,g < 1$. It gives for $\gamma_1\, b$ sufficiently great (> 1 or 2):

$$t\,g\,\gamma_1\, x = -\,cot\, 2\,\gamma_1\, b \qquad \gamma_1\, x = 2\,\gamma_1\, b - \frac{\pi}{2} - n\,\pi$$

In (40) only $Cos\,\gamma_1\, x$ varies numerically with n, which, therefore, should be taken as small as possible consistent with the condition that:

$$\gamma_1\, x < \gamma_1\, b$$

or

$$n > \frac{\gamma_1\, b}{\pi} - \frac{1}{2}$$

But (40) may be transformed to:

$$H^{\frac{5}{4}} = \frac{65\, P}{316{\cdot}2} \frac{Cos\,\left(2\,\gamma_1\, b - \frac{\pi}{2} - n\,\pi\right)}{Cos\, 2\,\gamma_1\, b}$$

or, approximately:

$$P = 4{\cdot}865\, H \sqrt[4]{H}\, e^{\frac{\pi}{2} + n\,\pi} = 23{\cdot}30\, H \sqrt[4]{H}\, e^{n\,\pi}$$

This is greater than the value corresponding to $x = 0$, which for any $\gamma_1\, b$ is:

$$P = 4{\cdot}865\, H \sqrt[4]{H} \frac{Cos\, 2\,\gamma_1\, b + cos\, 2\,\gamma_1\, b}{Sin\, 2\,\gamma_1\, b + sin\, 2\,\gamma_1\, b} \tag{43}$$

and for $2\,\gamma_1\,b$ sufficiently great:

$$P = 4{\cdot}865\; H \sqrt[4]{H} \tag{44}$$

Contrary to what was necessary in the case of the circular ice sheet lest G should be ∞, we suppose here ρ to be naught, as it simplifies the formulas without materially altering the results.

By means of formulas (37), (39), (41), (42), (43) and (44), the following table has been prepared:

TABLE II.—VALUES OF p IN POUNDS PER SQUARE FOOT AND P IN POUNDS PER LINEAL FOOT.

$2\,b$ (in ft.)		10		100			$\overline{\overline{>}}$ 1,000		
	γ_1	p	P	p		P	p		P
H (= 0·01 h) in inch.	$\frac{1}{27{\cdot}5\,H^{\frac{3}{4}}}$	$0{\cdot}044\,H^{\frac{1}{2}}\,\frac{Cos\,2\,\gamma_1 b + cos\,2\,\gamma_1 b}{Sin\,\gamma_1 b.\,sin\,\gamma_1 b}$	$4{\cdot}865\,H^{\frac{5}{4}}\,\frac{Cos\,2\,\gamma_1 b + cos\,2\,\gamma_1 b}{Sin\,2\,\gamma_1 b + sin\,2\,\gamma_1 b}$	x			$b - x$ $\frac{0{\cdot}7854}{\gamma_1}$	$0{\cdot}271\,H^{\frac{1}{2}}$	$4{\cdot}865\,H^{\frac{5}{4}}$
1	0·0364	2·65	13·38	25	0·25	4·77	22	0·27	4·86
2	0·0216	10·65	53·63	0	0·21	8·69	36	0·38	11·57
3	0·0160	23·74	120·06	0	0·30	14·50	49	0·47	19·20
4	0·0129	42·16	213·21	0	0·53	23·26	61	0·54	27·52
5	0·0109	66·37	333·64	0	0·70	34·93	72	0·61	36·36
6	0·0095	95·44	480·46	0	0·99	49·40	83	0·66	45·67
7	0·0085	129·50	651·95	0	1·32	66·30	92	0·72	55·40
8	0·0076	171·37	861·53	0	1·74	87·08	103	0·77	65·45
9	0·0070	215·44	1082·99	0	2·17	109·19	112	0·81	75·82
10	0·0065	262·07	1332·91	0	2·65	133·88	121	0·86	86·48
11	0·0060	323·79	1625·77	0	3·25	163·11	131	0·90	97·43
12	0·0056	388·70	1938·39	0	3·90	194·67	140	0·94	108·64

For small values of H both p and P corresponding to $2\,b = 100'$ are smaller than for wider spans; and for a 100 feet

span p is smaller for $H = 2$ than for $H = 1$. This seems at first sight absurd, but it is a consequence of our assumptions. The ice sheet with the wider span can, with the same curvature at the banks, better take advantage of the support of the water. And the thin sheet can bend down with a sharper curvature than the thicker ice; for the thinner it is, the less the fiber strain for the same curvature.

A comparison of the two tables reveals a radically different build of the formulas, as was to be expected, inasmuch as in the lake, the curvature is synclastic or anticlastic, in the canal cylindrical. P, for the lake, is the weight distributed over a circular area of radius 2 feet; for the canal it is the load per lineal foot acting over the whole length at the center of the canal. A comparison is, therefore, hardly possible; even taken for a length of 4 feet, it is considerably less for the canal than for the lake, as should be expected. The uniformly distributed load, p, is, on the contrary, greater for the canal than for the lake; the ice can bend down more readily to be supported by the water.

The ice here considered is pure, hard, glare ice. At temperatures above or a little below freezing point, its plasticity may make it yield to pressure and strains without becoming fractured.

ELECTRICAL SECTION.

Stated Meeting, Tuesday, October 22, 1895.

MR. CARL HERING, President, in the Chair.

SOME FORMULÆ FOR THE CALCULATION OF WIRES.

RETURN LOOP SYSTEM.

BY EDWIN R. KELLER, M.E.

It was formerly generally assumed that, by the return loop system of wiring, an absolute uniformity of potential at the lamps was attained. The incorrectness of this assumption was first pointed out by Mr. Osborn P. Loomis, in an article which appeared in the *Electrical Engineer*, about four

years ago. Mr. Loomis showed that the potential at the lamps was not constant, and stated that, while it was sufficiently so for all practical purposes, it was impossible to secure absolute uniformity.

The first part of Mr. Loomis' statement was evidently correct, but the other, viz.: that absolute uniformity could not be attained, was subsequently disproved by Mr. Clayton W. Pike, who demonstrated that, if, in connection with the ordinary return loop system (*Fig. 1*), additional wires be used, as in *Fig. 2*, or, if the gauge of wire be properly altered, absolute constancy of potential at the lamps could be secured.

Such an arrangement as that shown in *Fig. 2*, however, is of purely theoretical interest, and even the ordinary return

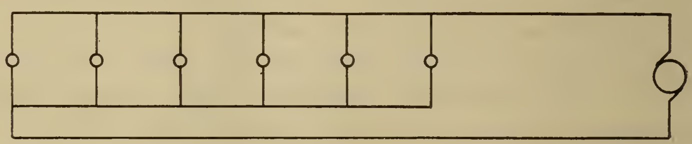

FIG. 1.

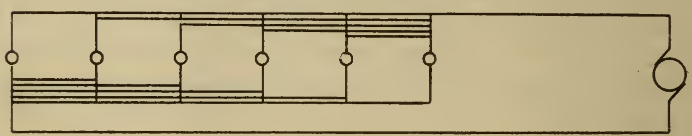

FIG. 2.

loop (*Fig. 1*) is rarely advantageous in practice, inasmuch as it involves the use of an extra length of wire, which (if conduit or moulding is used) would cost more than the saving effected in copper.

In the lighting of halls, lecture rooms, theatres, etc., it frequently occurs, however, that single lamps are distributed around the cornices, the whole circuit being controlled by a single switch. In this case architectural considerations usually require that the lamps be spaced evenly. The electrical problem is, then, how to wire in order to secure a minimum variation of potential at the lamps at the least expense for copper and conduit. The objection that an extra length of wire must be used in the return loop system no longer obtains, and it will be the object of this paper to determine

which of the methods ordinarily employed will give the most satisfactory results, and to present formulæ by which the wiring in such cases may readily be calculated.

There are three methods of wiring, which may be applied to cases of this kind: (*Fig. 3*).

In the first method we have simply the ordinary parallel system of distribution.

In the second, the loop closes on itself, so that the current is divided where it enters the circuit, one-half flowing in either direction.

The third, or return loop method, is similar to the first, except that the mains are run in opposite directions, so that the fall of potential is a maximum on the one, where it is a

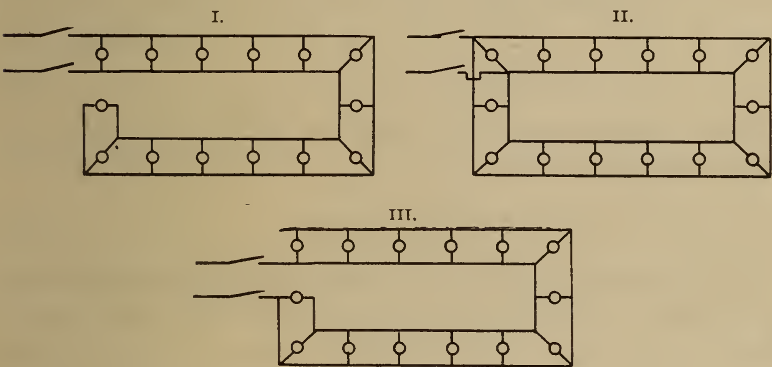

FIG. 3.

minimum on the other. At first sight, it would appear that the potential at all the lamps would be the same, and if this were the case, it would be sufficient to use a very small wire. That it is not, however, has already been shown by Mr. Loomis, and will appear presently from the formulæ:

Let c = current per lamp.

r = resistance per unit (foot) length of wire.

d = length of wire between any two lamps (single distance).

n = total number of lamps in the circuit.

E = the fall of potential.

In the first method the maximum difference in potential between any two lamps is evidently equal to the total drop

to the last lamp on the circuit. The drop from the first to the second lamp is

$$2\,rd.\,c\,(n - 1);$$

from the second to the third,

$$2\,rd.\,c\,(n - 2);$$

from the $(n - 1)$th to the nth,

$$2\,rd.\,c.$$

Hence the total drop to the last lamp,

$$E = 2\,rd.\,c\left[(n - 1) + (n - 2) + \ .\ \ .\ \ .\ (1)\right];$$

$$= 2\,rd.\,c\left\{\frac{\left[(n - 1) + 1\right]\left[n - 1\right]}{2}\right\};$$

$$= \quad rd.\,c\,(n^2 - n); \tag{1 a}$$

and the resistance per unit length of wire, which will give this maximum variation ($= E$) is

$$r_1 = \frac{E}{dc\,(n^2 - n)}. \tag{1 b}$$

In the second method the current is simply divided into two halves, one half flowing around each half of the circuit. Hence we have merely to substitute $\frac{n}{2}$ for n in the above formulæ.

$$E = \frac{rd.\,c}{4}(n^2 - 2\,n) \tag{2 a}$$

and

$$r_2 = \frac{4\,E}{d\,c}\,(n^2 - 2\,n). \tag{2 b}$$

In the return loop system the drop to any lamp, say the xth from either end, is, plainly,

$$E_x = dr.\,c\left\{\left[(n - 1) + (n - 2) + \ .\ \ .\ \ .\ \ .\ (n - x + 1)\right] + \left[(n - 1) + (n - 2) + \ .\ \ .\ \ .\ \ .\ (x)\right]\right\};$$

$$= \frac{dr.c}{2}(n^2 + 2\,n\,x - 3\,n + 2\,x - 2\,x^2); \qquad (c)$$

from which it is evident that the drop is not independent of x, and hence different at every lamp. Differentiating,

$$\frac{d\,E_x}{d\,x} = 2\,n + 2 - 4\,x = 0$$

$$x = \frac{n+1}{2}$$

It is a maximum when

$$x = \frac{n+1}{2},$$

that is in the middle of the circuit. The maximum drop is, consequently,

$$E_{\text{max.}} = \frac{drc}{4}(3n^2 - 4n + 1) \qquad (d)$$

It is a minimum when

$$x = n \text{ (or } 1);$$

that is, at either end of the circuit. Hence, substituting in (c) we have for the minimum drop,

$$E_{\text{min.}} = \frac{drc}{2}(n^2 - n). \qquad (e)$$

This last equation might have been derived directly from (1a), for, evidently, in the return loop system, the drop to the first or last lamp is equal to one-half the drop to the last lamp in the first system.

If now we subtract (e) from (d), we will obtain the greatest variation of potential between any two lamps in the circuit.

$$E = E_{\text{max.}} - E_{\text{min.}} = \frac{drc}{4}(n^2 - 2n + 1) \qquad (3a)$$

and

$$r_3 = \frac{4E}{dc\,(n^2 - 2n + 1)}. \qquad (3b)$$

We can now compare the relative economy of the three systems. The amounts of copper required are inversely

proportional to the resistances, and hence, if we call a_1, a_2 and a_3, respectively, the circular mills required in the three different systems to produce the same maximum variation in potential ($= E$), we have from (1*b*), (2*b*) and (3*b*):

$$a_1 : a_2 : a_3 = \frac{1}{r_1} : \frac{1}{r_2} : \frac{1}{r_3} = 4\,(n^2 - n) : (n^2 - 2n) : (n^2 - 2n + 1)$$

From this it appears that while the ordinary parallel system requires more than four times as much copper as the closed loop, there is very little difference between the closed loop and the return loop, though there is a slight advantage in favor of the second (closed loop) system. It must be remembered also that this comparison is made on the basis of a fixed maximum variation in potential between two lamps of the circuit, and not maximum total drop. From a consideration of the same total drop, the advantage in favor of the closed loop would be much greater. The amounts of copper would then be from (1*b*), (2*b*) and (*d*):

$$a_1 : a_2 : a_3 = 4\,(n^2 - n) : (n^2 - 2n) : (3n^2 - 4n + 1).$$

The following example will illustrate the use of the formulæ and show the results which would be attained in an actual practical case:

In a lecture room having 100 (110 v. 16 c. p.) lamps in five circuits, with a distance between the lamps of ten feet, and a maximum allowable variation of one volt between any two lamps, the resistance, by the ordinary parallel system, would be, from (1*b*):

$$r_1 = \frac{1}{10 \times \cdot 5\,(20 \times 20 - 20)} = \cdot 00053 \text{ ohms},$$

which corresponds to a No. 7 wire (B. & S. Gauge).

By the closed loop system it would be:

$$r_2 = \frac{4\,(20 \times 20 - 20)}{(20 \times 20 - 40)} \times \cdot 00053 = \cdot 00222,$$

which corresponds to a No. 13 wire.

And by the return loop system

$$r_3 = \frac{4\,(20 \times 20 - 20)}{(20 \times 20 - 40 \times 1)} \times \cdot 00053 = \cdot 00221,$$

which also corresponds to a No. 13 wire.

By the first two systems, however, the total drop would be but one volt, while by the return loop system the difference between the maximum and minimum would be equal to that amount. The drop to the first lamp would be from (*e*)

$$E_{\text{min.}} = \frac{10 \times \cdot 00221 \times \cdot 5}{2} (20 \times 20 - 20)$$

$$= 2 \cdot 09 \textit{ volts,}$$

and the drop to the middle of the circuit from (*d*)

$$E_{\text{max.}} = \frac{10 \times \cdot 00221 \times \cdot 5}{4} (3 \times 20 \times 20 - 4 \times 20 + 1)$$

$$= 3 \cdot 09 \textit{ volts.}$$

The same size wire in the second system gives a total maximum drop of one volt, and in the first system from (1*a*):

$$E = 10 \times \cdot 00221 \times \cdot 5 \, (20 \times 20 - 20)$$

$$= 4 \cdot 18 \textit{ volts.}$$

In other words, for the same maximum variation in potential in the three systems, the weights of copper would be, roughly:

208 : 52 : 52;

and the total drop

1 : 1 : 3·09;

while for the same weights of copper, the maximum variations in potential would be:

4·18 : 1 : 1;

and the total drop

4·18 : 1 : 3·09.

Some NOTES on ELECTRIC RAILWAY TESTS.*

Prof. Herman S. Hering presented to the Section "Some Notes on Electric Railway Tests," of which the following is an abstract, and which should prove of great value, and well worth the great amount of time and labor spent upon the collection of the data on which they are based.

The first point discussed was the importance of intelligent management of the controller by the motorman in order to obtain the best results. Starting too suddenly must be avoided, not only out of consideration for the comfort of passengers, but also because the mechanical strains would be serious and the motors would be working inefficiently. On the other hand, the cars must not be started too slowly, for the reason that the motors would work at a point of low efficiency, and also because the time of the trip would be lengthened. The cars should be allowed to "drift" as much as possible, so as to avoid waste of energy when brakes are applied.

Experimental trips, under careful observation, made with an expert and a non-expert motorman, under similar conditions, demonstrated that the expert accomplished the trip with the same number of stops and passengers as the non-expert, and with a saving in energy used of from 15 to 25 per cent. On a ten-mile road running fifteen cars, the saving from this source would amount to about $810.

The speaker next discussed the question of the loss of energy due to the sparking of the trolley wheel. This was found to be, for old wheels, as much as 250 watts; and for new wheels, 60 watts. Insufficient tension on the spring was said to be responsible, generally, for this loss, which may be obviated by careful inspection and adjustment of the springs.

The loss from imperfect contact between rail and wheels

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*Abstract of remarks made at the stated meeting of the Electrical Section of the Franklin Institute, held September 24, 1895.

was also determined, and, in the case of a track slightly sanded, was found to be about ·04 horse-power.

RECORDING AMMETER AND VOLTMETER.

At the same meeting, Professor Hering also described a "Recording Ammeter and Voltmeter," devised by him, for use in the tests above referred to.

As described by the speaker—and illustrated by sketches on the blackboard—this instrument consists of a Weston apparatus, in which the needle moves over a sharp metallic edge, with a strip of paper sensitised with calcium chloride between the needle and the sharp edge of the metal. One terminal of a small induction coil is connected to the needle, the other to the metallic edge, and the record is made by the spark in its passage through the paper from one to the other. The speaker exhibited curves taken with the instrument.

THE JOHNSTON RAIL-BOND.

At the same meeting, Mr. A. Langstaff Johnston exhibited several specimens of his rail-bond, which had been removed from the road-bed of the Hestonville Passenger Railway Company, Philadelphia. Mr. Johnston stated that the rails to which these bonds had been attached had been down for two years. The contacts between the iron of the rail and the metal of the bond, on the specimens shown, appeared bright and clean. From the experience with the bond gained on the line of this railway, Mr. Johnston stated that soldering the bond to the iron, which was originally done, had been found to be unnecessary.

CHEMICAL SECTION.

Stated Meeting of October 15, 1895.

DR. WM. C. DAY, President, in the Chair.

CARBIDES OF IRON.

BY F. LYNWOOD GARRISON.

In reviewing the history of the metallurgy of iron and steel, we find that ever since the recognition of the important role which carbon plays in the economy of this important industry, great efforts have been made to explain the phenomena, presumably due to carbon, which accompany certain metallurgical operations. The mere fact that carbon was known to exist in the metal in two distinct forms, graphitic and combined (the latter so-called for want of a more scientific definition), was not sufficient to explain to the inquiring mind such changes of molecular structure as take place in the cementation furnace; and that this particular problem is perhaps no nearer solution to-day than thirty years ago, is probably due, in great measure, to the fact that the process as a commercial operation has long since fallen into disuse. It has, of late, however, cropped up in a somewhat different form in the methods of face-hardening armor-plate by the addition of carbon, and possibly of chromium.

Although, within recent years, patents have been granted for increasing the combined carbon, and thus imparting additional hardness to articles of steel, as long ago as 1830, Karsten, in his researches upon the solvent action of acids upon iron and steel, observed a carbon compound which was evidently not graphite, and which must, consequently, be considered under the equivocal head of combined carbon. He did not succeed either in preparing or separating such a carbon compound having a definite chemical composition, but his observations led him to believe that carbon united with iron in such proportions that chemical union was effected, and that the

resulting body would probably correspond to the formula Fe_3C.[1] Berthier[2] claimed to have obtained a definite monocarbide, FeC, by the action of iodine and bromine upon steel. His observations, however, were never confirmed, and Caron[3] vainly attempted to produce this carbide by a similar solvent action of bromine, or iodine. Hence, the latter chemist concluded that the carbide of Berthier was a mixture of carbon and iron, in which the iron was mechanically protected from solvent action by the carbon. Berzelius[4] claimed to have obtained the carbide, FeC_2, by the distillation of ferrocyanide of ammonia; and another carbide, Fe_2C_3, by treating pure Prussian-blue in the same manner. Whether these residues were actual combinations of carbon and iron, or only mixtures of carbon and iron slightly carbonised, is doubtful. Percy[5] appears to regard their acceptance as definite compounds with reservation.

The first investigators to isolate a definite carbide from iron, were Müller and Abel, who, though working independently, appear to have obtained similar results.

Müller, like Karsten, obtained the carbide by the action of dilute sulphuric acid upon Bessemer steel, the resulting residue being pyrophoric, and containing from 6·01 to 7·38 per cent. of carbon. Hence he deduces the formula Fe_3C. Müller[6] remarks that, by the solvent action of the acid, a very large quantity of the total carbon must have been converted into hydrocarbons, since, by calculation, the carbon of the carbide is only from 20 to 50 per cent. of the total amount in the steel.

Abel obtained Fe_3C, by the action of a solution of potassium bichromate and sulphuric acid, containing just sufficient acid to dissolve the iron, since the amount of free sulphuric acid present greatly affects the yield of carbide. The carbide obtained by Abel[7] from several varieties of

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[1] *Manuel de la Metallurgie du Fer* (Metz, 1830), Vol. I. p. 173.

[2] *Ann. des Mines* (3), **3**, 229.

[3] *Comptes Rendus* **56**, 44; *Percy, Iron and Steel* (1864), p. 122.

[4] *Traité de Chimie* (1831), p. 270; *Percy, Iron and Steel* (1864), 122.

[5] *Metallurgy of Iron and Steel*, p. 123.

[6] *Zeitschrift des Vereins Deutscher Ingenieure*, **22**, 385.

[7] *Proceedings Inst. Mech. Engs.* (1885), 30–57.

iron, had a somewhat variable composition, as shown in the following analyses:

	H_2O. Per Cent.	C. Per Cent.	Fe. Per Cent.
Cold-rolled steel	0·93	6·92	92·77
Annealed steel	1·32	7·04	91·80
Tempered steel	2·28	7·23	89·92
Cold-rolled tempered steel	2·09	7·12	90·87

Less than 0.93 per cent. of the water is probably present as mechanically retained moisture, the greater part being a constituent of a carbo-hydrate resulting from the decomposition of the carbide, since this increase in the proportion of water is attended by an increase of carbon and a decrease of iron. The specific gravities of the carbide are, respectively, as follows:

From cold-rolled steel	6·9
From annealed-rolled steel	7·2

Abel[8] concludes that, at least in the unhardened steel, the carbide exists entirely as Fe_3C. Osmond and Werth[9], by submitting bars of steel to electrolysis in hydrochloric acid, and examining the residue microscopically and chemically, identified the carbide, Fe_3C, observed by Abel. They obtained it in brilliant magnetic scales or plates, and also observed that when a bar of steel is heated to redness it contains, besides carbides of iron, free carbon ("carbon libre"), the proportion of the latter increasing with increase of temperature.

The observations of Arnold and Read[10] show that a readily decomposable sub-carbide of iron exists, the iron of which is dissolved by the solvent, whilst the carbide escapes in the form of hydrocarbons. As a result of their extensive investigations, they arrive at the following conclusions:

(1) The "normal carbide"[11] exists in two forms of identical composition; (*a*) a diffused carbide scattered in microscopic granules, or very small plates, yielding on isolation a

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[8] *Ibid.*

[9] *Ann. des Mines* (8), **8**, 19 *et seq.*

[10] *Jour. Chem. Soc.* (Trans.), **65**, 788.

[11] They use the term "normal steel" to designate a steel heated to 1,050° C. and cooled in air. The normal carbide is, of course, the carbide from such a steel,—F. L. G.

grayish-black powder; (*b*) a crystalline carbide arranged in comparatively large distinct plates, in well annealed steel. These crystals are almost chemically pure Fe_3C, and are identical with the microscopical laminæ of Sorby's "pearly constituent."

(2) The percentage of total carbon obtained as carbide is greater in hard than in mild steel.

Iron containing	1	per cent. C.,	92	per cent. as carbide—loss	8	per cent.
" "	0·5	" "	87	" "	"	13	"
" "	0·25	" "	74	" "	"	26	"

This loss does not appear to be due to decomposition, but rather to the presence of an unstable sub-carbide of iron existing to the extent of 25 per cent. of the total carbon in the case of mild steel, and capable also of existing to a like amount in hard steel after it has been heated for some time at a white heat. The loss appears to be the same in well annealed, as in "normal steel," hence it cannot be due, as supposed by Ledebur,[12] to the presence of hardening carbon.

(3) The carbon in hardened steel exists chiefly in solution, or as a feebly combined and extremely attenuated carbide, leaving, on isolation, a residue consisting mainly of a hydrate of carbon mixed to a slight extent with normal carbide of iron. Whether the large loss of carbon (about 50 per cent. of the total) occurring during the decomposition of the hardened steel, is due to the presence of a considerable amount of sub-carbide, or to the evolved hydrocarbons, formed by the action of nascent hydrogen on finely divided, or feebly combined, carbon, there is no conclusive evidence to show, although the amount of evolved gas from hardened steel does not perceptibly exceed that from unhardened samples.

(4) In steel high in manganese (1·73 per cent.), a portion of the iron in the carbide may be replaced by manganese. The double carbide $Fe_7(Mn)C_3$, thus formed, is less stable than that of iron alone, especially in "normal steels." This double carbide is described as a uniform light-gray metallic powder.

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[12] *Jour. Iron and Steel Inst.*, No. 2, 1893, p. 53.

In connection with this observation upon the probable existence of a double carbide of iron and manganese, the researches of Troost and Hautefeuille are of interest. They found that, in uniting, manganese and carbon disengaged a great deal of heat and formed a stable compound Mn_3C, this evolution of heat being characteristic of all combinations of iron, manganese and carbon. Hence, all ferro-manganese alloys may be regarded as true chemical combinations. The amount of heat disengaged when these carbides were treated with bi-chloride of mercury appeared to vary according to the amount of carbon present.[13]

It is evident from this brief summary of the more important investigations upon the character of the simple carbides of iron, that we have to deal with a most complex chemical and metallurgical problem; and, although it may be urged that such investigations have yielded little of practical value, it must be manifest to anyone familiar with the subject that they may ultimately give us some definite and tangible knowledge of the chemical and physical properties of the various compounds, solids and gases which are of such vital importance in the constitution of the several varieties of iron which we have in commerce.

The futility of attempting to determine the character of some of these solid constituent compounds by a mere optical examination, without isolation and chemical analysis, must be evident, as witness the fact that Sorby's "pearly constituent." or "pearlite," has been proven by Arnold and Read to be simply the carbide, Fe_3C, long before observed and described. As everyone must have observed who has done much microscopical work with various opaque objects, reflected light, which must of necessity be used for illumination, is apt to play one tricks, and what, in one case, might appear to the eye as a distinct body, in another, may appear to be something quite different. As I have previously pointed out,[14] we have not in iron, as we have in rocks, a body composed of pre-determined compounds. To determine

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[13] *Comptes Rendus* **80**, 964.

[14] *Jour. Iron and Steel Inst.*, No. 1, 1895, p. 251.

the structure of a rock, the student has to familiarise himself with the characteristics of the minerals of which it is constituted. Since mineralogy may now be considered an exact science, it is a comparatively easy matter to master its essential details. In the case of iron, however, we practically know little or nothing of its constituent compounds; a chemical analysis exhibiting its composition, as so much iron, carbon, silicon, phosphorus, etc., gives us no more idea of its actual composition than would a similar analysis of a rock.

In both cases we obtain the ultimate composition of the body; that is, we would know with a fair degree of accuracy the total amounts of the respective elements present, but in no case does such an analysis give us more than a vague idea of the manner in which these elements are united amongst themselves. Following this line of reasoning, it must be evident that the only rational solution of the problem lies in first isolating, and then studying each one of the several constituent compounds (not elements) existin the iron, just as has been done in mineralogy and lithology.

Apparently, in accordance with this plan, Mr. James S. de Benneville, of Philadelphia, has recently devoted himself to the study of certain triple, or ternary, iron alloys, and with the result that he has discovered at least two new compounds, which are undoubtedly iron carbides.[15]

These carbides were obtained from specially prepared alloys of iron, chromium and tungsten, and of iron, chromium and molybdenum, respectively, by the action of dilute nitric acid (1·20 sp. gr.). The chromium-tungsten and the chromium-molybdenum were united in the ratio of 5 : 1. The carbides yielded on analysis, results corresponding, respectively, to the formula $Fe_7(CrW)_6C_4$ and $Fe_7(CrMo)_8C_4$. They are distinctly crystalline bodies (hexagonal prisms),

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[15] *Jour. Iron and Steel Inst.*, No. 1, 1895, pp. 202–253. It is but proper that I should state that this parallelism between lithology and iron metallurgy, is an idea of my own, for which Mr. de Benneville must not be held responsible; in fact, I do not know that he approves of it, since I have not heard him express his opinion upon the subject.—F. L. G.

and are similar in appearance. The crystals of chromium-tungsten are from $\frac{3}{100}$ to $\frac{4}{100}$ of an inch in length and $\frac{3}{1000}$ of an inch in diameter, and when heaped in masses have a decided yellowish metallic tint. The chromium-molybdenum crystals are of the same length, $\frac{5}{1000}$ of an inch in diameter, and when heaped have a dark steely-gray lustre. The specific gravity was 12·8 for the tungsten, and 7·473 for the molybdenum alloy; both were very feebly magnetic.

It is of interest to note in connection with this subject, that recently, Behrens and Van Linge[16] obtained, by treating ferro-chromium with fuming hydrochloric acid, what they describe as minute, rod-shaped (stäbchen), crystals, from 3 to 4 millimeters ($\frac{3}{25}$ to $\frac{4}{25}$ of an inch nearly) in length, non-magnetic; hardness 7·5. The chemical composition of these crystals varied with the ferro-chromium from which they were obtained; ferro-chromium with 13·8 per cent. chromium, 81 per cent. iron and 5·5 carbon, giving the compound $Cr_2Fe_7C_3$; whereas, with 50 per cent. chromium, the composition was approximately Cr_2FeC_2. The first compound they regarded as Fe_3C, in which iron is replaced by chromium; in the second, the increased carbon percentage may be considered as due to the high temperature necessary to produce the ferro-chromium. They ascribe the extreme hardness to carbon rather than to chromium, as much chromium remained in the part of the alloy which was soft. Chromium appears to facilitate the formation of a carbide, whose characteristics, even in pure carbon steels, are great hardness and chemical stability.

These statements are of interest, as being confirmatory of opinions, which I have on several occasions expressed, that, of itself, chromium does not harden steel.[17]

Within the past few weeks, Mr. de Benneville has obtained a similar crystalline substance from a ferro-chromium containing about 20 per cent. chromium. He has not yet determined its chemical composition, but it is presumably also a carbide. I have examined the crystals, and find

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[16] *Zeitschr. Anal. Chem.*, **33**, 513–533.

[17] *Jour, Iron and Steel Inst.*, No. 2, 1892, p. 151; *U. S. Geological Survey, Mineral Resources*, 1894, p. —.

them to be apparently hexagonal in type, but not so fully developed as those from the ternary alloys. They are also more minute, averaging about $\frac{3}{1000}$ of an inch in length, and $\frac{5}{10000}$ of an inch in diameter; being feebly magnetic, dark gray in color, and with steely lustre.

ADDENDUM.

An interesting illustration of the strong affinity between iron and carbon is afforded by the presence of a natural iron carbide in certain meteoric bodies. Cohen and Weinschenk[18] first observed this compound in the meteoric iron from Magura, Hungary, and Wichita County, Tex. It appeared in the form of crystals, "arranged parallel to an octahedral face;" was found to contain from 5·1 to 6·4 per cent. carbon, and from 1·5 to 3 per cent. nickel; hence should be regarded as a double carbide of iron and nickel; or, if the cobalt be considered, a triple carbide. These investigators named this compound Cohenite, and claimed that it corresponded to the compound Fe_3C, obtained from cast iron. From their analyses they derived the formulæ $(Fe,Ni,Co)_3C$ and $(Fe,Ni,Co)_4C$.

Derby[19] obtained quite a considerable amount of this carbide (Cohenite) from the Cañon Diablo, Arizona, meteorite. His analyses of two samples are as follows:[20]

	I. *Per Cent.*	*II.* *Per Cent.*
Fe	92·88	91·67
Ni + Co	1·33	2·43
P	0·48	0·09
C	5·33	6·07

Previous to the investigations of Derby, Koenig[21] claimed to have discovered diamonds and "amorphous carbon" in the Cañon Diablo meteorite. According to Derby, however, "nothing resembling that substance (diamond), or any other form of free carbon, could be detected."[22] This observation of Koe-

[18] *Ann. Nat. Hist. Mus. Wein.*, **6**, 131; *Dana's Mineralogy*, 1893, p. 1038.

[19] *Am. Jour. Sci.* (3), **49**, 101.

[20] *Loc. cit.*, 106.

[21] *Am. Jour. Sci.* (3), **42**, 415.

[22] *Loc. cit.*, 108.

nig's evidently lacks confirmation, and cannot be accepted as proven. Graphitic carbon was observed, years ago, in certain meteoric irons.[23] Now, as we have seen, definite carbides are formed; hence, it will be noted that, in this respect, the meteoric metal is analogous to the iron of commerce. The existence of carbon in the form of diamond in the meteoric metal is probably as unlikely as in the ordinary forms of iron; the mere fact that the temperature of the meteoric mass, when coming in contact with the atmosphere of the earth, becomes enormously increased, would be sufficient to dispel the supposition, since we know, from the experiments of Hempel[24] and Roberts-Austen[25] that carbon in the form of diamond unites more readily with iron at a red heat than either graphitic or amorphous carbon; consequently, admitting the carbon in the meteoric metal to be in the diamond form before the metal came in contact with the atmosphere, and before it was subjected to the resulting high temperature, we would naturally suppose, from our knowledge of the results obtained by these experiments, that the carbon would be changed from the diamond form, either by union with the iron as a carbide, or to the form of graphite.

NOTES AND COMMENTS.*

THE FUTURE OF THE ELECTRIC TELEGRAPH.

In the October impression of *The Engineering Magazine* appears an exceedingly interesting and suggestive paper from the pen of Mr. Patrick B. Delany, an acknowledged authority in this field, on the future of the electric telegraph, in which the author sets forth, in a most instructive way, the possibilities of an enormous extension of the use of the telegraph, and, incidentally, presents a strong argument in favor of Government ownership of the telegraphic systems.

We present in the following an abstract of this important paper, embodying the salient points of Mr. Delany's argument, and refer our readers to the original source for the paper in full:

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[23] *Am. Jour. Sci.* (2), **8**, 439; *ibid.* (2), **19**, 157.

[24] *Ber. der deutsch-chem. Ges.*, **18**, 998.

[25] *Jour. Iron and Steel Inst.*, No. 1, 1890, p. 81.

* From the Secretary's monthly reports.

"The future of the telegraph," says Mr. Delany, "will depend largely on the telegraph of the future. The telegraph of the present is, in its main features, the telegraph of the past; and, if it is to continue without material change, it is an easy matter to figure out its future, upon the basis of so many feet of wire for each inhabitant.

"We have now about 1,250,000 miles of wire to 65,000,000 people; but the probabilities are that, when we reach Mr. Gladstone's 400,000,000 mark, there will not be as many miles of telegraph wire as there are at present.

"It does not require much foresight to realize that the final destiny of the telegraph is to carry all correspondence of any urgency, and that the present method of hand-working, with its slow speed and multiplicity of wires, will give place to automatic or machine transmission, high speed, and fewer wires.

"At present, owing to the expense, the telegraph is used only in cases of urgency, commercial or social. If a despatch could be sent as cheaply as a letter, the mails would dwindle to a mere miniature of their present bulk. In the commercial aspect, it is simply a question of time against cost. Where 'time is money,' the telegraph claims its tolls. But there are degrees of urgency below the extreme which demand quicker communication than that afforded by the railway train; and the telegraph of the future will recognize these degrees of urgency, and provide for them. With the exception of the half-rate night messages, telegraph companies have never attempted to differentiate their facilities. Messages, as a general rule, have been forwarded in the order of filing. In a case of life or death, no one can acquire, by offering double, or a hundred-fold, the usual rate for a telegram, the right to insist on precedence. It is optional with the company to push the message ahead of comparatively unimportant traffic, or transmit it in its turn.

"There are fast trains, and fast steamers at premium rates, fast freights, and extra-delivery letters; but, except in the case of the night message, a telegram is a telegram, and haste goes only by favor. Common sense surely points to a change in this way of carrying on telegraphy. The Morse key, relay and sounder, with hand transmission, are, and will probably for a long time remain, indispensable for a certain class of business, *i. e.*, broker messages, train orders, and other despatches requiring instantaneous transmission. No automatic system requiring preliminary composing or preparation of messages will ever meet the requirements of the exchanges, between which transactions involving great amounts are made in a few seconds. * * *

"It is pretty well settled that the telegraph companies cannot go on increasing the number of wires. They themselves admit that, in future, increase of facilities will have to come either through automatic working or through a further multiplication of circuits derivable from a single wire, and of the latter there is little hope.

"The British post-Office recognised the inadequacy of hand telegraphy more than twenty years ago, and put in operation the Wheatstone machine system. Beginning with a speed of about fifty words per minute, the telegraph department, with praiseworthy persistency in the direction of higher speed, has gradually improved the system, until now it is carrying an enormous amount of traffic at speeds ranging from 100 to 400 words per minute, accord-

ing to distance and the character of the conductor. The system is also worked duplex, but at speeds less than double the simplex speeds.

"The Wheatstone system was introduced into this country about ten years ago, and, although it has not been extended as rapidly as might have been expected, it is firmly established on several of the most important routes, notably from New York to Chicago. Over this circuit 75 words per minute duplexed, or 150 words in all, are obtained. An automatic repeater is used at Buffalo, as through working is not practicable over the present wires.

"Now, while the Wheatstone system is a great advantage over the hand method for heavy traffic, it can never, in the nature of things, be the telegraph of the future—that is, if the great bulk of correspondence is to be carried by telegraph. * * *

"Giving the Morse and Wheatstone systems full credit, it is my opinion that the system for carrying the mass of correspondence now carried by mail will be one of employing automatic transmission, and chemically prepared paper for reception of signals—a system having no electro-magnets, no armatures or movable parts, no springs or contacts to adjust, and no inertia to overcome, and one that is not thrown out of adjustment by slight changes of the circuit. The chemical plan of recording is based upon electrolysis. The saturated strip of paper forms a part of the circuit, and its sensitiveness for speed is at least twenty times greater than that of any electro-magnetic recorder.

"Davy is credited with the discovery that the passage of an electric current through paper moistened with certain chemicals would leave a mark in the track of the scraping finger, under which the paper ribbon was drawn. Alexander Bain was the first to use this discovery for recording telegraph signals. His automatic system of about forty years ago met with some success, but it had numerous defects, both mechanical and electrical. The perforating machine for preparing the message for transmission was crude, slow, and unreliable. 'Tailing,' or running together of the signals, making it difficult to separate the dots from the dashes, was the chief electrical difficulty.

"During the past twenty-five years chemical telegraphy has at different times engaged the attention of numerous able inventors, and considerable progress has been made towards overcoming the difficulties in the way of complete success. * * *

"Recent improvements in the perforating machine, transmitter, and receiving instrument, for automatic chemical telegraphy, have at last brought this ideal plan of rapid communication to a degree of perfection which cannot fail to bring about sweeping changes in transmission of correspondence in general. Between New York and Philadelphia, over a copper wire weighing 300 pounds to the mile, 3,000 words per minute can be recorded perfectly; and, with a copper wire weighing 850 pounds to the mile, 1,000 words per minute can be carried from New York to Chicago. It is between such large centres and over such long distances that the importance of such an achievement can be appreciated. The field for such a system lies between the present telegraph rate of, for example, 40 cents for

10 words from New York to Chicago, and the letter by rail, occupying nearly 30 hours, for 2 cents. At a speed of 1,000 words per minute over one wire, it is estimated that a 50-word message can be perforated in New York, transmitted automatically, typewritten, and dropped in the post-office in Chicago at an actual labor cost of 3 cents, to which the cost of the stamp must be added. Two wires of the character named, worked to their highest capacity, would carry all the letters now exchanged between New York and Chicago (provided their average length is not more than 50 words), and all the messages handled by the telegraph companies as well.

"When it is once proven practicable to deliver 1,000 words per minute in plain Morse characters over a circuit 1,000 miles in length, all prejudices hedging about old systems and methods of handling business should be swept aside. A perforator and a type-writer will, in effect, be a sending operator, and a receiving operator, and about forty will be employed at each end of a single wire. * * *

"As late as twenty years ago nearly every business man wrote his own letters, and very bad chirography jogged along by mail train at 20 miles an hour. Now, probably over 90 per cent. of the business letters are dictated to stenographers, and plain typewriter print speeds along at 40 miles an hour. The letter of the future will be dictated to a stenographer, who, instead of typewriting it, will perforate it on a paper tape. This tape will be sent to the telegraph office, where it will be put through the automatic transmitting machine, and in a second or two it will be at its destination. The receiving tape will be delivered direct, and the plain Morse characters will be translated on the type-writing machine by the correspondent's stenographer. Commercial houses having a large business will do their own perforating and translating, thus securing important reductions from the regular tolls. For them the telegraph company will be simply a carrier, having nothing to do with their correspondence but putting it through the machine. Nor will such messages be read by any of the company's employees, any more than open letters are now read by postal clerks. This will practically render all correspondence secret, as the perforated slip may be withdrawn as soon as it has been used. The contents will not be forced upon the notice of the telegraph operator as it present. Newspapers, railway companies, or other large corporations which now frequently have to resort to ciphers and codes to prevent 'leakage,' will welcome this privilege of protecting their secrets. A few weeks' practice is all that is necessary for learning to read the Morse characters with great facility from the paper tape, and proficiency on the perforating machine may be reached in the same time, so that to the already varied accomplishments of the typewriter will be added perforation and translation of telegraphic correspondence. Translation from Morse characters will be easier than from stenographic notes, with none of the elements of doubt attaching to the latter. * * *

"Speculation as to the future of the electric telegraph would be within extremely narrow bounds if the question of Government control were not considered. It may be somewhat remote, but it is hard to avoid the conclusion that the Government will not always draw the line as to the vehicles to be

employed for carrying its mail. It now uses over 3,000 railway cars on 150,000 miles of road, and keeps 6,000 clerks on the move, traveling in crews 140,000,000 miles a year, during which time 9,000,000,000 pieces of mail matter are handled. About 300 mail cars are wrecked, a dozen clerks killed, and 150 injured during the same period. The total expense of the postal service is about $75,000,000 per annum, and the department is not far from self-sustaining. How can so vast a system ignore the difference between railway and electrical speeds? A car travels 40 miles an hour, a current 200,000 miles a second. The automatic chemical telegraph will send a message of 16 words from New York to Chicago every second, and 50 words—about the average of a business letter—in 3 seconds. If time be reckoned as the basis of value for correspondence, which will appeal most to the business man—a letter occupying 24 hours in covering 1,000 miles for 2 cents, or a telegram going the same distance in 3 seconds for 15 cents? Would not a very large proportion of business communications warrant the extra 13 cents? * * *

"Neither the Constitution nor any Act of Congress places limit or restriction on the mode of mail-carrying. The giant proportions and rapidly increasing power of telegraph interests of late years, coupled with the difficulties presented by the political aspect of the case, doubtless account for the fact that to-day the United States is the only country that does not control its telegraphs. Other Governments took them over in comparative infancy, when it was an easy thing to do, and telegraphy has thus become engrafted into their general schemes of communication. The use of the telegraph in many countries of prominence is much more general than in America, notwithstanding the fact that nearly all the improvements—notably Hughes' printer, the duplex, quadruplex and synchronous multiplex systems in their practicability—came from America. The British Post-Office, without prejudice or jealousy, took all these in their turn, and concurrently developed their own Wheatstone system, until to-day, for reliability, accuracy and uniformity of time, its telegraph service is unequaled.

"The British telegraph has not paid its way. It almost reached the maintenance point a few years ago, but the telephone inroads on its business became too great. The deficit is attributed mainly, however, to the enormous amount of press reports carried at very low rates. At night, the first charge of a shilling on a 100-word message having been paid, the message may be duplicated as many times as desired to any part of the United Kingdom for 4 cents.

"In foreign countries, as with ourselves, popular rates have not been available, owing to slow methods of operating; but, now that automatic working is supplanting the hand system, important changes may be looked for. Already Italy, having introduced the Wheatstone system, is about to make the experiment of 5-cent telegrams.

"It seems inevitable that, sooner or later, in this country, the Government will use the telegraph, either in a monopolistic or a competitive way. It cannot go on restricting the postal service to hauling of actual paper by rail. Among other of its beneficent aims, its mission is to place its people in com-

TEST OF AMERICAN ROTARY SNOW-PLOWS ON THE PRUSSIAN MILITARY RAILWAY, AT MAHLOW.

munication by the quickest means at the lowest cost, and for this purpose the telegraph alone will answer. There can be no more striking example of the public desire for quick facilities of communication than is shown in the avidity with which they have taken advantage of the quick-delivery system instituted by the post-office a few years ago. Every such letter is an evidence that the writer is willing to pay 10 cents in order to expedite the delivery of his letter half an hour. If these letters could be telegraphed for, say, 15 cents, or 3 cents more than the ordinary and extra postage, no one can doubt that nearly all would go that way."

THE SCHEFFLER-KURTH ROTARY SNOW-SHOVEL.

At the stated meeting of September 18th, Dr. Robert Grimshaw made some remarks upon the introduction of American rotary snow-shovels in Europe, especially in Germany, illlustrating them on the screen by a photographic view taken on one of two trials made in the latter part of last winter, on the Prussian Military Railway at Mahlow, near Berlin. (See accompanying illustration.)

The speaker explained that the use of rotary snow-shovels in Central Europe had not been demanded at all for commercial reasons, nor (by reason of the usually moderate snowfall) for military purposes. But the severe snows of last winter, blockading so thoroughly so many of the railways of Europe, caused apprehension in military circles, lest future snowfalls should prevent the rapid transportation of troops and materials of war from one strategic point to another; hence, the German Government looked into the matter for military rather than for commercial reasons.

It being found impossible to get any regular railway to make a trial of the Scheffler-Kurth shovel at its own cost, or even at the builders' expense, the use of a section of Government military railway (which is distinct in management and purpose from other regular governmental railways) was obtained and a snow-heap built thereon, 600 meters in length and from 2½ to 4½ meters high. To build this it was necessary to haul some twenty train-loads of snow from the streets of Berlin, in addition to what could be obtained in the neighborhood. The compacted mass as presented for removal by the shovel, was composed of partly-frozen slush, and had a specific gravity of 0·750. The results of the first test (made under conditions much more severe than ever met with in actual railway service) were but partially successful, by reason of the too rapid advance of the train, due to nervousness and inexperience of the engine-runners; but a second trial, two days later, with a snow-heap of similar compactness and height, and 1,000 meters in length, demonstrated most satisfactorily the superiority and efficiency of the American system of snow removal.

The machine tried on this occasion has a twin-cylinder, single-expansion, double-acting vertical engine of 800 horse-power, driving a shaft 10 inches in diameter, at the forward end of which is a rotary shovel 10 feet in diameter and having twelve blades fastened firmly to a pointed hub at the end of the shaft, and to a peripheral wrought-iron ring. Across this latter there is a

strong diametral breaker-bar, in advance of the blades, and serving to cut the snow when frozen, thus relieving the blades. This shovel rotates in an adjustable cylindrical boiler-iron case, open in front, and having in its periphery a side outlet, the position of which can be so changed by partial rotation of the case (effected through clutch-gearing, by the main engines) as to throw the snow in a continuous stream either to the right or to the left of the track, and at any desired angle from horizontal to vertical. This obviates the necessity of reversing the engine, as is done in most American rotary snow-shovels. In addition to its partial rotation, the case may be slightly raised at switches and crossings. The entire machinery is mounted in a specially constructed box-car. Steam for the twin engines is furnished by a spiral copper pipe from a locomotive directly coupled the to rear of the shovel-car; and the exhaust passes through a similar spiral pipe to the smoke-box of this locomotive. This latter could, if sufficiently powerful, have given the necessary advance to the shovel-car; although, on this occasion, a second locomotive was employed for pushing.

Two of these machines have been in successful operation for two winters on the Government railways in Hungary.

THE KÖPCKE SPRING RAIL-JOINT.

At the same meeting, Dr. Robert Grimshaw also described a spring rail-joint, the invention of Prof. Dr. Köpcke, of Dresden.

The invention is designed to give both vertical and lateral stiffness to the joint, while permitting lengthwise expansion of the rails. To make it in an ordinary T-rail, two lengthwise saw-kerfs are made in the web for about one foot at each end separating the web from the head and the flange respectively. The head is then entirely removed by a cross cut for about the same length, the web bent inwards at right angles and the flange bent downwards, also at right angles. These bent portions may then be united to corresponding portions of a similarly-treated rail, by bolts or rivets; suitably spaced holes having been punched before the bending. A fish-plate may be used on the outside of the rails if desired.

PROSPECTIVE INCREASE IN THE CONSUMPTION OF IRON.

In an article recently published in the *Engineering Magazine*, Mr. Edward Atkinson ventures the prediction that from the present time until 1900, the consumption of iron in this country may be expeeted to increase, not only in the present ratio to the increase of population, but also in an accumulated ratio corresponding to the increase *per capita*, which was developed between 1877 and 1889. Assuming, as he does, that the consumption *per capita* will rise only from 300 to 400 pounds, "then the 80,000,000 people who will occupy this country in the year 1900 may require, in addition to our present supply, not less than 7,000,000 gross tons.

Making the assumption that the demand of Great Britain, France Germany, and Belgium shall increase only twenty per cent., that increase will create a demand in 1900 for 2,000,000 tons in addition to their present con-

sumption. If the consumption of the rest of Europe, of Asia, of Africa, of South and Central America and of Australia shall increase from eleven or twelve pounds *per capita* to twenty-two or twenty-four pounds, this, in addition to their present supply of 60,000,000 tons, will require 6,000,000 tons more.

He, thereupon, summarizes the results of these prospective increases in the demand for iron, showing, on the basis of his assumptions, that the world's prospective demand for iron in 1900 will be not less than 40,000,000 tons.

W.

TIN-PLATE PRODUCTION IN THE UNITED STATES.

The report of special agent Ira Ayer, of the Treasury Department, on the condition of the tin-plate business in the United States, exhibits a substantial growth of the industry. During the fiscal year ended June 30, 1895, the production in the United States of commercial tin- and terne-plates was 193,801,073 pounds, against 139,223,467 pounds during the previous fiscal year, showing an increased production of 39 per cent. Of the production for the year, 160,576,934 pounds, or about 83 per cent., were made from sheets rolled in the United States, against about 62 per cent. for the fiscal year ended June 30, 1894. The quantity of sheets of American manufacture used during the last fiscal year was 31,253,467 pounds in excess of the entire production of commercial tin- and terne-plates during the fiscal year ended June 30, 1894. The production for the year, distributed according to weight and kind of plates, was as follows:

Fiscal Year Ended June 30, 1895.	Lighter than 63 Pounds per 100 Square Feet. Pounds.	63 Pounds per 100 Square Feet and heavier. Pounds.	Total. Pounds.
Tin-plates	103,256,143	17,071,806	120,327,949
Terne-plates	62,934,216	10,538,908	73,473,124
Total	166,190,359	27,610,714	193,801,073

The production of black plates in the United States during the fiscal year, by quarters, was as follows:

Quarters.	Lighter than 63 Pounds per 100 Square Feet. Pounds.	63 Pounds per 100 Square Feet and heavier. Pounds.	Total. Pounds.
1894. September 30	26,681,855	5,570,511	32,252,366
1894, December 31	16,801,660	8,805,543	25,607,203
1895, March 31	37,751,102	11,388,665	49,139,767
1895, June 30	67,229,153	11,342,990	78,572,143
Total	148,463,770	37,107,709	185,571,479

Total production for the fiscal year ended June 30, 1895, 185,571,479 pounds; same, fiscal year ended June 30, 1894, 98,970,880 pounds; increase, 86,600,599 pounds, or 87½ per cent.

The total imports during the fiscal year ended June 30, 1895, were 513,963,401 pounds; total exports for the same period, 126,777,800 pounds; net imports, 387,185,601 pounds; total domestic production, 193,801,073 pounds. Approximate consumption in the United States, 580,986,674 pounds; average annual capacity of mills completed June 30, 1895 (144), say, 450,000,000 pounds; same, of mills completed and in course of construction, June 30, 1895, say, 570,000,000 pounds.

From Colonel Ayer's previous reports, and from the foregoing abstract, the editor of the *Bulletin* of the American Iron and Steel Association has compiled the following table of the production of tin-plates and terne-plates in the United States, from July 1, 1891, when the tin-plate duty of the McKinley tariff went into effect, until June 30, 1895, or exactly four fiscal years:

Fiscal Years.	Tin-Plates. Pounds.	Terne-Plates. Pounds.	Total. Pounds.
1892	4,539,590	9,107,129	13,646,719
1893	45,743,107	54,076,095	99,819,202
1894	81,609,765	57,613,702	139,223,467
1895	120,327,949	73,473,124	193,801,073

TECHNICAL NOTES.

Apropos to the approaching completion of the trans-Siberian railway, to the accomplishment of which the Russian Government is directing all its energies, it is suggested that it might be found desirable to extend the American system of railways northwardly to Alaska, to a terminus at Behring Strait, on the Pacific, by which connection could be established, through a system of train ferriage across the Strait, between the American and Asiatic-European railway systems. This connection, if realised, would make possible a *continuous journey by rail between Paris and New York.*

Metallic lactates are strongly commended to electroplaters by Dr. Jordis, in a communication made to the German Electro-Chemical Society. He affirms that lactic acid affords an excellent solvent in electroplating baths, and yields good, adherent metallic deposits. He reports that he has succeeded in obtaining from lactate baths, coatings of copper and brass, of varying shades, on iron, zinc and copper; of zinc on iron and copper; and of iron on nickel. Silver lactate yields a pure white coating of silver on amalgamated brass, which takes a high polish.

An ingenious method for the *illumination of opaque objects* for examination under the microscope, and which is said to be applicable to even the strongest magnifications, has been devised by Mr. Charles Fremont, and

is described and illustrated in the *Scientific American*, of October 12, 1895. Mr. Fremont's method consists, briefly, in effecting the illumination through the interior of the tube of the microscope, and of the objective, by means of an adjustable concave mirror, and a prism suitably arranged within the tube, and which receive the light from an exterior source through an aperture in the side of the microscope tube, and direct it vertically upon the object under examination. The concave mirror and prism are provided espectively, with an opening through which a conical tube passes inside of, and in the vertical axis of, the microscope tube, and which permits the object to be viewed without interference from the admitted light. The arrangement is pronounced to be much superior to other artifices heretofore employed for the same purpose. W.

BOOK NOTICES.

Engineering Contracts and Specifications, including a Brief Synopsis of the Law of Contracts and Illustrative Examples of the General and Technical Clauses of Various Kinds of Engineering Specifications. Designed for the use of Students, Engineers and Contractors. By J. B. Johnson, C.E., Professor of Civil Engineering, Washington University, St. Louis, Mo., etc. First edition. Engineering News Publishing Company, New York. 1895. Price, $4.00.

It has too long been the reproach of our schools of engineering that the training which they give their pupils is too largely theoretical, and especially, that the business side of engineering is too little taken into account, so that the graduates proved to be in too many cases highly educated young gentlemen, quite incapable of doing anything in particular until they had unlearned most of what they had acquired.

Professor Johnson, himself a most able instructor, and yet pre-eminently a practical man, whose recent work on the "Theory and Practice of Modern Framed Structures" is now the standard work on that subject, goes a long way, in the present volume, to remove this reproach by making the student acquainted, as well as can be done by the printed page, with what may be called engineering business.

The work differs from that of Professor Haupt, which has been before the public for a number of years, chiefly in discussing at considerable length the law of contracts.

Although the author disclaims any intention of supplanting the professional lawyer, he nevertheless avows his object of rendering it in many cases unnecessary to call in the services of that functionary, by pointing out to the engineer the legal pitfalls which he may avoid.

Nearly 300 pages are occupied by well-chosen examples of modern specifications by prominent engineers, whose names are given, and not only the student but the practicing engineer will find it well worth while to study carefully the author's discussion of contracts and specifications. T.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 20, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, November 20, 1895.

JOS. M. WILSON, President, in the chair.

Present, 195 members and visitors.

Additions to membership since last report, 15.

Dr. Robert Grimshaw described, with the aid of lantern pictures, a number of "Machine Shop Wrinkles," consisting of novel and ingenious tools, mechanical artifices and expedients, etc., used in notable machine shops, and which had fallen under his observation in various places.

Mr. Patrick B. Delany, of New York, described and gave an exhibition of the operation of his system of machine telegraphy. The invention involves a system of mechanical transmission and electro-chemical reception of messages, and is capable of being operated at surprisingly high speeds. Mr. Delany dealt with the proposition of substituting the telegraph for the railways as a means of conveying correspondence, which would require a great enlargement of telegraphic facilities and cheapening the cost of transmission. The speaker gave a brief historical review of past and present systems, and of the growth of telegraphic communication. His new fast system of telegraphy, the speaker claimed, demonstrated the entire feasibility of practically supplanting a large and important portion of the present mail service by telegraphy.

Mr. Delany's remarks and demonstrations were received by the meeting with cordial approbation. At the close of the discussion which followed, on the motion of Mr. Thos. Shaw, numerously seconded, the thanks of the meeting were voted to Mr. Delany for his interesting and important communication. (Mr. Delany's paper will appear in the *Journal.*)

On motion of the same member, the meeting voted to refer the subject of Mr. Delany's system to the Committee on Science and the Arts for investigation and report.

Under new business, Mr. John Shinn presented and had read by the Secretary, a preamble and resolution setting forth the need of amending the patent law of the United States and the rules of procedure in the Patent Office, and asking for the appointment of a special committee to investigate and report upon the subject. The president held that the proposed investigation did not lie within the province of the Institute, and accordingly pronounced the subject to be out of order.

Adjourned.

WM. H. WAHL, *Secretary.*